# Journal
## of
# The Franklin Institute

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

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Journal
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# SOME THUNDERCLOUD PROBLEMS.*

BY

C. T. R. WILSON, F.R.S.

Fellow of Sidney Sussex College and Jacksonian Professor of Natural Philosophy in the University of Cambridge
Franklin Medalist

As a follower of Franklin in the study of the electricity of thunderclouds it is specially gratifying to me to be honoured by the award of the medal named after him. It seemed to me appropriate that I should speak on this occasion about thundercloud electricity.

I shall therefore try to put before you the picture which many years' observations of the electrical fields of thunderclouds have led me to form of some of the processes which are concerned in the origin or which may follow as effects of these fields. It need hardly be said that the conditions in actual thunderclouds must be very complicated and varied and that any picture we can usefully form has to be an ideally simple one.

Franklin himself concluded that the surface of the earth below a thundercloud was generally positively charged as shown by the loss of positive charge from his discharging points. And later observations agree with Franklin. As we should now express it, the potential gradients below thunderclouds (which generally reach values of the order of 10,000 volts per meter) are much more often negative than positive,

* Presented at the Stated Meeting held Wednesday, May 15, 1929. Read by Professor John Zeleny, head of Department of Physics, Yale University.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

and the resulting currents from earth connected discharge points are preponderatingly upwards. Observations like Franklin's but quantitative have been made in England by Wormell and in South Africa by Schonland and have shown that the upward currents through natural point dischargers must make an important contribution to the interchange of electricity between the earth and atmosphere.

It was shown first by Simpson and has been confirmed by many observers that on the whole rain carries down a considerable excess of positive electricity. At first sight the most natural conclusion would seem to be that the fall of positively charged rain leaves in the thundercloud a negative charge and that this is the explanation of the negative potential gradient below the cloud.

The view I wish to put before you is a very different one. According to it a thundercloud is essentially bipolar, the positive charge tending to be above the negative. The preponderance of negative potential gradients below shower clouds and thunderclouds is on this view due primarily to the negative charge of the cloud being nearer the ground than the positive; the cloud may in addition acquire an excess of negative charge when the loss of positive charge by conduction to the upper atmosphere exceeds the loss of negative charge to the ground. The prevailing positive charge on rain is on this view not the cause but the result of the negative potential gradient; the rain intercepts and returns to the earth a portion of the charge carried by the stream of positive ions which are being driven up by the negative potential gradient.

There would probably be general agreement that the source of the electromotive force of a thundercloud is to be sought in the vertical separation under gravity of carriers of positive and negative electricity.

Let us suppose that the small particles in a cloud, which only fall slowly relatively to the air, are positively charged, while the larger drops which fall with considerable velocity through the air are negatively charged. We may leave for the present the question how the carriers acquire their charges.

Such a cloud, originally neutral, will at once begin to acquire a positive charge at the top and a negative charge at the bottom through the relative vertical motion of the two

classes of carriers. The two equal and opposite charges thus accumulating at the top and bottom may be separated by a great thickness of neutral cloud. The accumulation of a positive charge above and a negative charge below results in the development of an electric field within the cloud, which tends to hinder the negative drops from falling and the positive particles from being carried up by the air stream.

The rate of accumulation of the upper and lower free charges and the resulting rate of increase of the field will become less as these charges increase for two reasons. The field within the cloud opposes the falling of the negative drops and the carrying up of the positive cloud particles; and again the dissipation of the upper and lower charges by ionization currents or otherwise increases as the charges increase. There may come a stage where a balance is reached and no further increase in the field results; or on the other hand the field may reach the sparking limit before such a balance can be attained, and we have then a lightning flash.

If such a discharge destroys the vertical field within the cloud while still leaving the positively and negatively charged carriers, the destruction of the field will be followed by its regeneration through the separation of the carriers by gravity; initially at the maximum rate, since no field is opposing the fall of the negatively charged drops relative to the positive carriers and there is no loss of charge by ionisation currents or otherwise until there are charges to dissipate. The rate of increase of the field will again continually diminish as the upper and lower charges accumulate. If these processes continue to be repeated we must suppose that new carriers are supplied to take the place of those which have been removed.

Dissipation from the upper and lower charges will not generally be equal; the cloud may thus acquire a net charge, positive or negative.

Observations on thundercloud electricity have generally to be made at the ground. We have therefore to examine how the results of such observations compare with the effects to be expected from our ideal thundercloud. Measurements of the field changes produced by lightning discharges have been carried on at the Solar Physics Observatory, Cambridge, since 1914; in recent years many measurements have been made

elsewhere by Appleton and Watson Watt (who have studied especially the effects of very distant discharges) by Schonland (in South Africa) and by others.

I shall consider some results of measurements made during thunderstorms in which the discharges were observed to be within the thundercloud and which followed one another at considerable intervals so that the effects of successive discharges were not superimposed.

The changes in potential gradient observed in such storms by means of recording apparatus are just such as would follow from the destruction of the field within a bipolar cloud in which the positive pole was uppermost. The potential gradient destroyed at the earth's surface is positive when the discharge is distant, negative when it is near; after each distant discharge the positive potential gradient is regenerated, at first rapidly and then at gradually diminishing rate, an automatic record showing a characteristic recovery curve.

Now when the discharge is distant the field-change must be proportional to the electric moment destroyed in the cloud; the moment being the product of the positive charge by its vertical distance above the negative. Thus observations on the field changes due to distant discharges of this type give us, when the distance is known, the sign and magnitude of the electric moment destroyed and the rate at which it is regenerated.

The average magnitude of the electric moments destroyed by discharges of the type under consideration is about $10^{16}$ when expressed in electrostatic units and centimeters (i.e. about 30 coulomb-kilometers). The initial rate of regeneration is frequently about one-tenth of the whole magnitude per second.

Another important magnitude is the intensity of the electric field required to produce a discharge in the presence of drops of the size to be expected in thunderclouds. Direct experiments suggest that this critical field is in the neighbourhood of 10,000 volts per cm. or about 33 electrostatic units.

From a knowledge of these three magnitudes we may deduce some interesting information about the interior of the thundercloud.

Let us assume that the effective portion of the cloud has

horizontal upper and lower limits. From the magnitude of the field which is required to cause discharge we can deduce the positive charge which must accumulate at the top per unit area before an internal lightning flash occurs; the vertical field being $4\pi$ times this charge per unit area. Now the electric moment $M$ is the product of the positive charge $q$ which has thus separated at the top by its height above the equal negative charge which has separated at the bottom. It is thus equal to the charge per unit area $\times$ area $\times$ vertical thickness, i.e. to $F/4\pi$ times the volume, where $F$ is the magnitude of the field required to cause discharge.

The volume required for the production of an electric moment of $10^{16}$ electrostatic units is found in this way to be about 4 cubic kilometers. This is of course a lower limit for the volume of the thundercloud.

The electrical energy stored in the cloud and dissipated at each lightning discharge is $\frac{1}{2}qV = \frac{1}{2}qFh = \frac{1}{2}MF$. If we put the moment $M$ equal to $10^{16}$ and the maximum field equal to 33 e.s.u. we obtain for the energy of the lightning discharge about $1{\cdot}6 \times 10^{17}$ ergs or $1{\cdot}6 \times 10^{10}$ joules.

The value found for the maximum potential difference in the cloud depends on the vertical thickness, i.e. the distance through which the maximum field $F$ extends. We can hardly be wrong as to the order of magnitude if we take this height as one kilometer. If a field of 10,000 volts per centimeter extends through one kilometer the whole potential difference is $10^9$ volts, i.e. one million kilovolts.

The initial rate of regeneration of electric moment after a discharge gives further information as to the conditions in the type of cloud we are considering. Very frequently about one-tenth of the maximum moment is regenerated in the first second; the initial rate is thus about $10^{15}$ c.g.s. units per second.

Since the electric force within the cloud and the positive charge accumulated at the top are proportional to the electric moment they also increase at the rate of about one-tenth of their final value per second. The increase of positive charge per unit area, in other words the vertical current per unit area in the cloud, is in this way found to be about one quarter e.s.u. per square centimeter per second, or about one ampere per square kilometer. This is the initial magnitude of the

upward current immediately after a discharge and is due to the separation under gravity of the positive and negative carriers; there is initially no field to retard this separation.

We might take the rate of production of electric moment as giving us the product of the rate of increase of the upper positive charge by its vertical distance above the negative. It may also be regarded as the product of the combined charge carried by all the positive carriers throughout the cloud by their vertical velocity relative to the negative carriers.

Now there cannot be much doubt as to the order of magnitude of this velocity; it must be comparable with the velocity of rain drops relative to the air, i.e. a few meters per second. Let us take it as 600 cms. per second, the rate of fall of drops of about one millimeter radius.

This gives for the total charge on either the positive or negative carriers in the neutral cloud $1 \cdot 6 \times 10^{12}$ e.s.u. or about 500 coulombs.

When the maximum field of 10,000 volts per cm. or 33 e.s.u. is reached, the force holding up the whole mass of negatively charged drops will be $33 \times 1 \cdot 6 \times 10^{12}$ dynes $= 5 \times 10^{13}$ dynes; it will support the weight of $5 \times 10^{10}$ grams of water. Now even when this stage is reached the drops must still have some weight to spare over that required to balance the electric force holding them up; for the rate of separation of positive and negative charges must be sufficient to supply the losses by dissipation even if a steady condition of the field has been reached. The weight of the negatively charged drops in the cloud must therefore have exceeded $5 \times 10^{10}$ grams; or, dividing by the volume (4 cubic kilometers) which we found for the effective portion of the cloud, about 12 grams per cubic meter. (This is equal to the weight of water in a cubic meter of saturated air at about 14° C.) Unless the weight of water in the negatively charged drops in a cubic meter of the air exceeded 12 grams their charge would be sufficient to cause them to be held up by the field of 10,000 volts per cm.; i.e. their charge per c.c. of water would be about 30 e.s.u.

An urgent question now arises; can we in any way account for the large charges acquired by the carriers?

According to Simpson's well-known theory the rain drops

in a thundercloud acquire a positive, not a negative charge as the interpretation of the phenomena of thundercloud fields which we have taken requires. And there are difficulties, which have been pointed out by Simpson and others in Elster and Geitel's influence theory, Another process which depends, like that considered by Elster and Geitel, on the influence of a previously existing field, has I think to be taken into account.

This would depend on the presence of ions in the cloud; in strong fields the positive ions would require to be of small mobility such as would result from their attachment to nuclei or small cloud particles.

A netural drop falling through the air in a field of positive potential gradient, at a speed greater than that with which the positive ions are being driven by the field, will absorb negative ions at its lower positively charged surface; positive ions cannot reach its negatively charged upper surface from above as they cannot overtake the drop. It is only positive ions which the falling drop has overtaken (or in other words which have been carried up by the air from below the drop) that can approach its upper negatively charged surface; and these have all already suffered repulsion by the lower positive half of the drop before they come under the influence of the upper negatively charged half. The originally neutral falling drop will at first catch only negative ions; and in air of equal conductivity for ions of both signs, it will continue to catch more negative than positive electricity till a resultant negative charge is acquired amounting to a considerable fraction of the induced charge.

The induced charge on each half of a spherical drop is proportional to the area of cross section and to the field. For a drop of one millimeter radius in a field of 10,000 volts per centimeter it is about $\frac{1}{4}$ e.s.u. If the drop acquires a resultant negative charge of 1/10 of this amount (increasing the upper negative charge by 1/20 and diminishing the lower positive charge by an equal amount) the net charge will be about 6 e.s.u. per c.c. of water. A drop of 1/10 mm. only requires to gain a negative charge equal to 1/20 of the induced charge in order that its net charge per c.c. may reach the amount (about 30 e.s.u.) required for its weight to be supported by a

field of 10,000 volts per cm. In a thunder cloud of the type we are considering it is only for a small part of the time between two discharges that the field is much below the maximum.

Let us assume that sufficient ionization occurs and that the positive ions have their mobility reduced to that of the ordinary large ions; these will move through the air with a speed of a few cms. per second in a field of 10,000 volts per cm. Then all drops which are large enough (more than a few thousandths of a cm. in radius) to fall faster than these positive ions are moving will acquire negative charges; the charge per c.c. except in the case of the largest drops may approach that required to make the field support the weight of the drops. Drops smaller than the critical size will acquire positive charges.

The principal source of ionisation in the active thundercloud is probably the field itself. This is likely to act mainly by drawing out any specially large drops into pointed form and making them into very efficient point dischargers; experiment shows that a field of rather less than the magnitude assumed has this effect on drops exceeding about 2 mm. in radius.

The acquisition by the drops of the large charges which we have to postulate to explain the rapid regeneration of the field after each discharge may perhaps occur in some such way as that which has just been outlined. The original building up of the field of the cloud may be much more gradual; in the initial stages the fine weather positive potential gradient is likely to determine the sign of the polarity of the cloud; and the charges will be at first acquired from the ordinary ions set free by ionizing radiations.

Let us consider now some effects outside the thundercloud. A bipolar cloud of positive polarity will produce at the ground below it a negative potential gradient. Except for a short interval after a discharge the gradient is generally sufficient to cause point discharges and thus an upward current of positive ions. Raindrops which were negatively charged in the cloud will generally not only lose their negative charges but acquire a positive charge in falling through the upward stream of positive ions. Even when the field is insufficient to

cause point discharges the fall of drops through the air exposed to the normal sources of ionization will in a field of negative potential gradient result in the drops acquiring a positive charge by a process like that which we have supposed to give them their negative charge when in the cloud.

The preponderance of positively charged rain may thus be the result of the preponderance of negative potential gradients below shower clouds.

Above the bipolar cloud of positive polarity the electric force will be directed upwards as it is below the cloud; at any height at all large compared with the dimensions of the cloud the electric force will be proportional to the resultant electric moment of the cloud and its image.

If the conductivity of the air in the next few kilometers above the thundercloud were no greater than the normal fine weather conductivity at the same height the upward current maintained through it by the thundercloud would not be large. But the field of the thundercloud will itself add to that conductivity in three ways. Negative ions drawn out of the highly ionized upper atmosphere will increase the conductivity of the layers below. Positively charge droplets may be driven up from the portion of the cloud which lies above the level of maximum potential till they travel out beyond the region of saturation and eventually evaporate with liberation of their ions (possibly the driving of these droplets from the cloud into the unsaturated atmosphere may give rise to false cirrus). Thirdly electrons accelerated by the electric fields both within and above the thundercloud will converge towards and finally be stopped within the positively charged region, producing the maximum ionization there.

A bipolar thundercloud with positive pole uppermost is thus a source of electromotive force which maintains an upward current from the earth to the conducting upper atmosphere. The cloud will generally acquire an excess of positive or negative charge according as the dissipation of the lower or upper charge is the greater.

The observed phenomena relating to the electric field are in agreement with the view that most, possibly all, thunderclouds are of this nature, and they suggest that in the more severe storms the negative charge is in excess.

My own experience has been that when discharges between cloud and earth were frequent the resulting changes of field indicated that the discharges were mainly carrying positive electricity upwards from the earth to the cloud. It is probable that in many cases both poles were discharged, the lower being negative and carrying the larger charge.

There is now strong evidence that both by continuous discharge and by lightning flashes an upward electric current is maintained by showerclouds and thunderclouds and that this exceeds the oppositely directed current brought down by rain.

I have long held that we must look to showers and thunderstorms as the main agents in the maintenance of the negative charge on the earth in fine weather regions; that they act as electric generators which remove positive electricity from the earth and supply it to the conducting upper atmosphere by which it is distributed over the whole earth. The upper atmosphere is thus maintained at a potential of nearly one million volts.

According to Brookes there are on an average nearly 2,000 thunderstorms in action at a given moment. An upward current of one ampere per thunderstorm would be more than sufficient to balance the downward current of the fine weather regions.

We should expect the total number of thunderstorms to be a maximum when the most thundery regions of the earth were in the position with respect to the sun most favourable for thunderstorms. And if the thunderstorms are the cause of the fine weather field the resulting daily variation in the total number of thunderstorms in action should be associated with a simultaneous daily variation in the fine weather potential gradient. It was pointed out some years ago by Mauchly, that the investigations of the Carnegie Institute on potential gradients over the oceans indicated that the maxima and minima in the daily variations occur simultaneously over the whole globe. Whipple has recently shown that there is a close parallelism between the curves of daily variation of total number of thunderstorms and of fine weather potential gradient over the whole earth.

According to Brookes there are about 100 lightning dis-

charges per second; this is probably an underestimate. One of their most important effects is the emission of atmospherics. I shall not attempt to deal with this side of thunderstorm electricity.

If we take the estimate already made for the energy of a lightning flash ($1 \cdot 7 \times 10^{10}$ joules) we obtain for the total rate of dissipation of energy in lightning flashes at 100 per second $1 \cdot 7 \times 10^{12}$ watts i.e. more than one thousand million kilowatts or $10^{19}$ ergs per second. And this represents by no means the whole expenditure of electrical power by thunderclouds.

The important factor in the electrical power of the thunderclouds is the electromotive force, since this exceeds anything which we are likely to attain by artificial means. We obtained for the order of magnitude $10^9$ volts, i.e. one million kilovolts. It is quite likely that voltages several times as great may occur in great thunderclouds; we cannot however have voltages as great as ten times this value, since this would require a field of 10,000 volts per cm. to extend throughout the whole height of the stratosphere.

The main interest in having available sources of energy reaching the magnitudes attained in thunderclouds would consist in the possibility of giving to electrons or atomic nuclei energies enormously exceeding those associated with alpha and beta particles from radioactive substances. Attempts to derive high potentials from thunderclouds for such purposes are I believe being made in different parts of the world.

The process of imparting energy to electrons must always go on naturally in thunderclouds on a scale that we cannot hope to imitate. For in the intense field of a thundercloud an electron, which has already kinetic energy corresponding to a comparatively few kilovolts and is moving anywhere nearly in the direction along which the field would carry it, will lose by collisions much less energy than it receives from the field; it will in consequence continually increase in energy, while the chance of its being stopped by accidents of any kind becomes less and less as its energy increases. It is not impossible that in this way an electron may acquire energy corresponding to nearly the whole electromotive force of the thundercloud; in this way energies approaching or even exceeding that emitted

as radiation on the destruction of a proton (about $10^9$ volts) might be attained. Such ultra-beta particles would have ranges comparable with the whole thickness of the atmosphere.

There is then a possibility that ultra-beta particles from the region of maximum negative potential in a thundercloud may sometimes reach the upper atmosphere with a large part of their energy unexpended. Any such electrons will describe helical paths of large radius around the magnetic lines of force and finally enter the lower atmosphere at widely separated parts of the earth. It is plain that these ultra-beta particles would not be intercepted by mountains surrounding the place of observation. Millikan's experiments made under these conditions do not then rule out the possibility that thunderclouds may contribute to the penetrating ionizing radiations which are generally regarded as being entirely of cosmical origin.

It may seem to some of you that I am putting forward too many claims on behalf of the thundercloud. If that is so perhaps I may be forgiven for magnifying the rôle of the thundercloud in a lecture associated with the name of Franklin.

# VOCAL PHYSICS—HISTORIC NOTES.*

BY

**EMILE BERLINER,**

Member of the Institute.
Franklin Medalist.

THE Science of Electricity, in the second half of the nineteenth century, brought forward several practical applications in branches of electro-acoustics. In 1876, A. Graham Bell first presented to the world the undulatory magneto-electric telephone. It was first displayed and demonstrated to the public at the great Centennial Exposition of 1876 which was held in Philadelphia, and which was due in origin to the activities of The Franklin Institute.

Early in the following year the writer of this paper utilized the qualities of the loose electrical contact for causing an existing electric current to produce perfect electric speech waves by means of variations of pressure. These variations of pressure were effected by the speech itself which it was desired to transmit. Strength, sensitiveness and distance were thereby added in electrically transmitted conversations. The manipulation took place by means of drums or diaphragms which acted upon Bell's magnet as well as upon the loose contact. The motions of the diaphragm caused variations of the pressure upon the loose contact and consequent variations of its electrical resistance, and in this manner a speech current was set up by fluctuations in the loose contact, and flowed through the latter. As the drum of an animal's ear is damped by the pressure of tiny bones in the ear cavity and muscles attached to them, and is steadied thereby and kept free from mixed and harmful vibrations, so the pull of the magnet steadied the diaphragm in the Bell magneto instrument and kept its vibrations free from distorting components. A set of flat pressing springs served a similar purpose in the early microphones of the Blake type. Later microphones of the Hunning or radio type accomplished the requisite damping of the diaphragm by the slight weight of the numerous carbon

* Presented at the Stated Meeting held Wednesday, May 15, 1929. Read by Dr. Howard McClenahan, Secretary.

grains which formed many loose contact microphones, already preconceived in Berliner's patent caveat of April 14, 1877.

The study and understanding of the control of electrical currents, as used in the telephone and microphone produced by, and producing, variations of the energy of sound, and of all the allied phenomena, have grown almost beyond the bounds of belief, and have lead to the development of the greatest of the electrical organizations, the telephone industry and science. The two rooms occupied in Boston in the world's first telephone factory, by Watson and Berliner, and in which a number of the earlier microphone problems were solved, have had as their lineal descendants the countless telephone buildings for production and operation, which spot the surface of the earth. The first practical microphone, the Blake, was perfected and made reliable by the writer in that first Bell Laboratory; there, the first twenty thousand of these microphones were personally tested by him in 1879 before they were shipped to its agents by the Bell Telephone Company. In the library of the Bell Company there is preserved the author's description of his laboratory work, in perfecting the Blake transmitter.

I had always believed that while sound was being transmitted across a microphone contact point, between two conducting points in 'contact,' there was in reality no true touching of the points, but that the two points were separated by a film of air of varying thickness; that if true contact should be established the microphonic action would cease, and sound would not be transmitted.

In November, 1926, Mr. Roy M. Allen and I photographed with a high power microscope such a microphonic contact while sound was being transmitted across it. We used a special microphone consisting of two adjustable iron pins and employed a microscope having a magnifying power of approximately five hundred diameters. The microphone contact was photographed when the sound of the ticking of a watch and the whirring of the wheels were being transmitted. The illustrations clearly show the film of air separating the metals and the microphone through which sound was transmitted. When this film disappeared by pressure, the sound was no longer heard. The suggested theory of microphonic action seems indisputably proved by these photographs.

The success of these photomicrographs is due in chief part to the high experimental skill of Mr. Roy M. Allen of Bloomfield, N. J., former president of the New York Microscopic Society, to whom I make grateful acknowledgment.

Soon after his invention of the microphone, the writer found that a loose contact, in addition to serving as a transmitter, could act also as a receiver without the help of a Bell telephone. Utilizing this discovery, he devised the application of a double coil which up to the time had been used only as a current interrupter. This closed double coil was interposed as a continuous current transformer between transmitter and receiver, and vastly extended the usefulness of the telephone, and, later, of the radio as well. In the latter apparatus, the transformer is used to impress the variations of current set up by the microphone upon the high frequency carrier currents.

An interesting example of the manner in which one art can supplement another is found in an attempt which was made by the writer in 1880 to use a shellac composition as a substitute for the expensive hard rubber of the Bell Telephone receiver. This effort was not a success, the material was too brittle—but, in 1895, exactly the same compound completely solved the important problem of finding a substance out of which could be made an unlimited number of perfect copies of gramophone sound discs. This fact is but little known. "The stone which the builders rejected has become the head of the corner."

The writer's contribution to the development of the talking machine consists in the substitution of a record groove of uniform depth on the horizontal disc in place of the helical groove of varying depth in other systems, cut upon cylinders. In the Berliner instrument, the vibrations of the needle produced by the sounds to be recorded cause a horizontal record of even depth in the horizontal plane. The amplitude of the propulsion of the needle, which is determined by the loudness of the sound recorded, causes the engraving needle or chisel, to cut into the side walls to different distances, and so the varying sound record is recorded.

In this method, the record is cut into the wax in exact proportion to the energy exerted by the voice on the recording diaphragm; whereas, in the method of the phonograph or graphophone, the vertically cut record is continuously changed

by the uneven resistance of the matter into which it is cut. Furthermore, the use of the groove of uniform depth permits of the elimination of the delicate feed screw of the old apparatus. In the Berliner disc, the groove itself produces the motion of the needle across the disc at the proper rate. This greatly simplifies the apparatus and eliminates one of the great sources of disturbing sounds.

In recent years, the writer's scientific interest and labors have been devoted to an effort to solve the age old problem of producing proper acoustical conditions in auditoria and public halls. A method has been perfected which seems to me to assure the happy solution of this problem.

In this method of treatment, portions of the auditorium walls, about one-fourth of the total area under the ceiling, are covered with wire cloth diaphragms over which is spread a special porous cement mixture which, when finished and hardened, forms a smooth cement wall surface which can, if desired, be ornamented. Hundreds of cement diaphragms are thus formed which are as vibratory as the sounding boards of pianos. They diffuse, and do not merely reflect, the sounds from singers and speakers and other sources which fall upon them. This diffusion has a marked tendency to prevent reverberations as well as echoes. This treatment, as applied in many places, has been successful in producing satisfactory acoustic conditions and in promoting ease of speaking and singing. In one instance, the owners of a music hall reduced the usual orchestra by nearly one-half, yet still found the volume of sound in the room satisfactory after the treatment with these sound diaphragms.

Absorption has previously been relied upon to eliminate reverberations and other disturbing sounds. The Berliner treatment seems to offer a thorough substitute for methods which depend entirely upon absorption and which seem to the writer to accomplish even more desirable results. Of course floors cannot be covered with the sonant diaphragms or with absorbents other than carpets. Furniture and audiences must be depended upon to prevent disturbing sounds which would proceed from empty and reflecting floor spaces. Audiences filling a small part, say a quarter, of the floor space are usually effective in preventing sound disturbances proceeding from the floor.

# THE PROPERTIES OF DIELECTRICS: PART II. THE DIELECTRIC CONSTANT.*

BY

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WHEN an insulating medium is placed under voltage, prominent among the phenomena to be observed are electric conduction and, under certain conditions, dielectric rupture. Each of these has been described in previous papers of this series.[1,2] Electrical conduction and dielectric rupture are factors markedly dependent upon the purity of the material under test. Perhaps a more fundamental property is the force existing between the charges applied to the dielectric.

With parallel plane electrodes, the distribution of this force is uniform.

$$F = 4\pi Q. \qquad \text{I}$$

This expression, however, applies only for electrodes spaced $d$ distance apart in a vacuum. If air or other medium be substituted the force becomes proportional not to the charge ($Q$) per square centimeter of electrode surface but to a certain function of this quantity. The expression, therefore, becomes:

$$F = \frac{4\pi Q}{\epsilon}. \qquad \text{II}$$

The quantity $\epsilon$ is dependent on the insulating medium and is known as the dielectric constant. The force existing between the charges for different materials thus becomes inversely proportional to this quantity, other factors being held constant. The dielectric constant may be expressed,

* Paper prepared at the request of the Committee on Insulation, Division of Engineering, National Research Council, Dr. J. B. Whitehead, Chairman.

[1] H. L. Curtis, *A. I. E. E.*, 46, 1095 (1927).

[2] W. A. Delmar, W. F. Davidson and R. H. Marvin, *A. I. E. E.*, 46, 1002 (1927).

therefore, as the ratio of the force existing between unit charges in a vacuum to the force between the same charges in the medium under test..

$$\epsilon = A_1/A_2. \qquad \text{III}$$

Stated otherwise, the quantity of electricity able to be stored with a given electrode spacing changes from one medium to another by a factor represented by the ratio $\epsilon_2/\epsilon_1$, where $\epsilon_2$ is the dielectric constant of the medium in question and $\epsilon_1$ the dielectric constant of the basic material.

The study of dielectric constant is particularly important in the design and manufacture of electrical equipment in order to obtain the proper distribution of electrical stress. It is the peculiarity of these stresses to accumulate in those materials where the maximum force per unit charge can be exerted. Thus with direct current voltages the electrical stress is distributed in proportion to the resistivities of the media in series. With alternating current voltages the charges tend to accumulate in the medium of the lowest dielectric constant. With pure materials, therefore, the charges, whether of D.C. or A.C., accumulate invariably in the layer of the lowest dielectric constant since, as will be illustrated in later paragraphs, such materials usually possess the highest resistivity characteristics.

Numerous cases might be cited to illustrate the importance of the dielectric constant to the "practical" engineer. In cable manufacture, graded insulation is used to reduce the stresses at the point of maximum value next to the conductor and increase the stresses nearer the lead sheath, thus securing a more even distribution throughout the insulating body. Such graded insulation is usually obtained by a variation in the density of the paper used. Vacuum-oil treatment of insulation produces not only decreased losses and increased dielectric strength but changes as well the dielectric constant of the material treated through the elimination of gas and air and the introduction of a higher dielectric constant material, oil. Cable manufacturers have studied carefully the problem of void or gas formation in cables under stress. The presence of such areas is made doubly dangerous because of the low dielectric constant. This tends to increase still more the

stress concentration in an area already weakened from one cause or another.

Transformer designers must carefully consider the dielectric constant of the materials used in their apparatus. The existence of oil ducts in series with solid insulation must be carefully planned in order to avoid over stresses in those materials of low dielectric constant. Capacitor manufacturers are continually searching for higher constant materials to increase the capacity and decrease the cost of their product. For low voltage application this is especially important because of the thickness limitations of the solid dielectric used. Laminated pads less than one or two mils in thickness have been found unsuited for factory manufacture. Dielectric constant and resultant stress distribution must also be considered as playing an important part in the design and manufacture of high voltage bushings, cable joints, etc.

The property of dielectric constant is closely woven into the fundamental structure of the atom or molecule. Those molecular or atomic factors which are most closely associated with chemical reactivity are also the factors of greatest importance in determining dielectric constant. Thus chemical reactivity not only concerns the type of compound under investigation but involves as well the type of reacting groups, their location in the molecule, the mass of the parent molecule and the proximity within the molecule of other related or non-related groups. The same considerations apply with equal force to the property of dielectric constant.

#### THE EFFECT OF TEMPERATURE ON THE DIELECTRIC CONSTANT OF GASES.

In gases, we do not have the possibility of electrolytic ionization with resulting molecular motion within the electric field. The disposition of charges within the molecule may be such, however, as to allow molecular orientation and setting in the field. In such instances, the center of gravity of the positive charge does not coincide with the center of gravity of the negative charge and molecular moment results. In the union of two like atoms such as these of hydrogen, molecular moment is usually very weak or entirely absent. Such molecules are therefore of low dielectric constant and show but little temperature effect in accordance with dictates of equation IV (Debye):

$$P = \frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{M}{D} = \frac{4\pi N}{3}\gamma + \frac{4\pi N}{3}\frac{\mu^2}{3kT}, \qquad \text{IV}$$

in which $P$ = molecular polarization,

$M$ = molecular weight,

$N$ = number of molecules per gram molecule ($6.061 \times 10^{23}$),

$\gamma$ = molecular polarizability,

$K$ = molecular gas constant = ($1.372 \times 10^{-16}$),

$T$ = absolute temperature.

In this expression $\mu^2/3kT$ is the mean component of the moment per molecule in the direction of the internal field of unit strength. As $T$ is the only variable on the right hand side of the expression, it is evident that, when the molecule contains no permanent doublet ($\mu = 0$), the second term on the right disappears and the equation becomes equivalent to the Clausius-Mossotti equation:

$$\frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{M}{D} = \frac{4\pi N}{3}\gamma = K. \qquad \text{V}$$

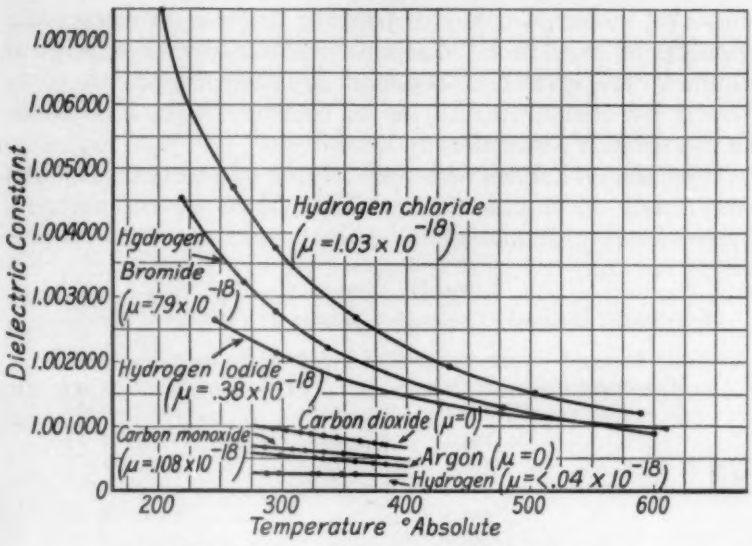
TABLE I (FIGURE 1).

*The Dielectric Constant-Temperature Relation for Non-Polar Gases (Braunmuhl[3]).*

| Hydrogen. | | Argon. | |
|---|---|---|---|
| Abs. Temp. | Dielectric Constant (760 mm.). | Abs. Temp. | Dielectric Constant (760 mm.). |
| 288.8 | 1.000275 | 296.0 | 1.000530 |
| 295.2 | 1.000268 | 297.0 | 1.000525 |
| 326.7 | 1.000246 | 299.4 | 1.000522 |
| 329.7 | 1.000245 | 327.0 | 1.000475 |
| 371.2 | 1.000225 | 327.7 | 1.000476 |
| 383.0 | 1.000225 | 331.8 | 1.000469 |
| | | 342.6 | 1.000457 |
| | | 359.4 | 1.000431 |
| | | 368.6 | 1.000430 |
| | | 372.3 | 1.000422 |
| | | 383.0 | 1.000401 |

[3] H. J. V. Braunmuhl, *Phys. Z.*, 28, 141 (1927).

FIG. 1.




The effect of temperature on polar and non-polar gases.

TABLE II (FIGURE 1).

*The Dielectric Constant—Temperature Relation for Carbon Dioxide (Braunmuhl[3]).*

| Abs. Temp. | Dielectric Constant (760 mm.). |
|---|---|
| 292.0 | 1.000938 |
| 292.8 | 1.000934 |
| 296.2 | 1.000905 |
| 303.0 | 1.000905 |
| 304.4 | 1.000904 |
| 307.7 | 1.000905 |
| 308.2 | 1.000897 |
| 314.9 | 1.000878 |
| 323.5 | 1.000830 |
| 332.2 | 1.000819 |
| 333.8 | 1.000820 |
| 336.6 | 1.000812 |
| 342.9 | 1.000786 |
| 343.6 | 1.000798 |
| 363.7 | 1.000787 |
| 361.3 | 1.000757 |
| 362.3 | 1.000747 |
| 362.7 | 1.000751 |
| 371.8 | 1.000724 |
| 372 8 | 1.000720 |
| 376.0 | 1.000710 |
| 379.0 | 1.000715 |
| 381.5 | 1.000702 |
| 383.0 | 1.000693 |

In the union of two chemically different atoms to form a compound molecule it is still possible to have an electrically symmetrical structure. Carbon dioxide furnishes a good example. Its dielectric constant is accordingly but little affected by temperature. In its characteristics it behaves like the simpler gases already described.

The halogen halides represent a series of gaseous molecules with finite electric moment. The effect of temperature becomes more pronounced.

TABLE III (FIGURE 1).

*The Dielectric Constant—Temperature Relation for Polar Gases (Zahn [4]).*

| Gas. | Abs. Temp. | Dielectric Constant (760 mm.). |
|---|---|---|
| Hydrogen Chloride | 201.4 | 1.007452 |
| ($\mu = 1.03 \times 10^{-18}$) | 260.1 | 1.004716 |
| | 294.2 | 1.003792 |
| | 359.2 | 1.002672 |
| | 433.9 | 1.001948 |
| | 503.9 | 1.001526 |
| | 588.8 | 1.001182 |
| Hydrogen Bromide | 217.5 | 1.004545 |
| ($\mu = .79 \times 10^{-18}$) | 269.0 | 1.003209 |
| | 294.4 | 1.002796 |
| | 338.9 | 1.002228 |
| | 478.5 | 1.001303 |
| | 599.1 | 1.000943 |
| Hydrogen Iodide | 244.5 | 1.002687 |
| ($\mu = .38 \times 10^{-18}$) | 295.1 | 1.002123 |
| | 345.9 | 1.001760 |
| | 474.6 | 1.001239 |
| | 612.2 | 1.0009706 |

## MOLECULAR POLARITY.

The existence of molecular polarity is of major importance in physics and chemistry. If the molecule has moment it is surrounded by an electric field the intensity of which diminishes approximately as the cube of the distance. With no moment, the molecule is surrounded by an electric field whose intensity decreases at a much higher power. Polar molecules will therefore possess more intense fields and will, as a result, attract and be attracted more strongly to neighboring molecules. The existence of such fields has been used to explain

[4] C. T. Zahn: *Phys. Rev.*, 24, 400 (1924): 27, 329, 455 (1926).

the catalytic effects produced by polar molecules on chemical reactions.

The presence of water vapor promotes the union of hydrogen and oxygen; that of hydrogen chloride promotes the union of hydrogen and chlorine. The field of the water or of the hydrogen chloride molecule attracts molecules of hydrogen and oxygen or of hydrogen and chlorine. Each acts, therefore, as a nucleus of condensation, bringing about closer contact of the reacting molecules and thus promoting chemical combination. Since the products of the reaction in both instances cited are polar, reactions of this type tend to be explosive.

The presence of a polar molecule may be detected in a variety of ways. The Lorenz [5]-Lorentz [6] expression for refraction

$$\frac{n^2 - 1}{n^2 + 2} \cdot \frac{1}{D} = k,$$

in which $n$ is the refractive index, is found approximately equal to the polarization in many cases, as would be expected from the well-known Maxwellian [7] relation, $\epsilon = N^2$. The dielectric constant involves the setting of the molecule as a whole in the electric field. Polar molecules will, therefore, be expected to show a higher dielectric constant. Since, however, this molecular setting will be sluggish, it would not be expected to be affected by light waves of the visible spectrum. The refractive index measured for such molecules will therefore not be in accord with the dielectric constant as expressed by Maxwell.

The effect of temperature change has also been used successfully for the detection of polar molecules.

Equation Number IV states

$$P = \frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{M}{D} = \frac{4\pi N}{3}\gamma + \frac{4\pi N}{3}\frac{\mu^2}{3kT}.$$

Thus, with finite moment, the dielectric constant diminishes as the temperature rises due to thermal agitation. Badeker [8]

[5] L. Lorenz, *Ann. Physik*, 11, 70 (1880).
[6] H. A. Lorentz, *Ann. Physik*, 9, 641 (1880).
[7] J. C. Maxwell, "Treatise on Electricity," Vol. II, Oxford (1881).
[8] Badeker, *Zeit. f. Physik Chem.*, 36, 305.

has in this way definitely identified gaseous compounds, such as those of water, ammonia and hydrogen chloride as polar.

More complete studies in the field of dielectric constant as affected by temperature should give valuable information concerning the electrical symmetry of gaseous molecular compounds.

#### THE EFFECT OF PRESSURE ON THE DIELECTRIC CONSTANT OF GASES.

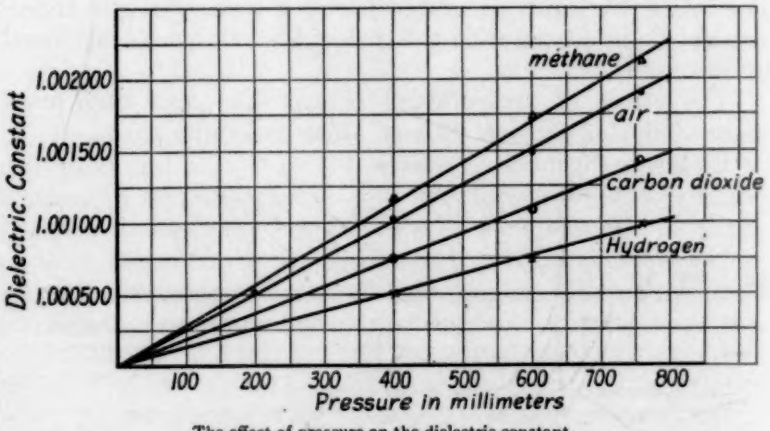
The conception of the property of dielectric constant for a vacuum is of difficult interpretation. Accepting its value as unity, however, the existence of dielectric constants of higher value has been suggested to depend upon the presence of molecular dipoles the effect of which reduces the force between electrical charges in accordance with equation II, which is

$$F = \frac{4\pi Q}{\epsilon}.$$

The reduction of the attractive force between electrical charges must necessarily depend not only upon the molecular dipole moment but, for a given moment, upon the number of molecular dipoles per unit volume. The dielectric constant therefore becomes a function of pressure.

$$(\epsilon - 1) = f(P). \qquad \text{VI}$$

FIG. 2.




The effect of pressure on the dielectric constant.

TABLE IV (FIGURE 2).

*The Effect of Pressure on the Dielectric Constant (Riegger).*

| Air ($T$ = − 185.5° C.) | | Hydrogen ($T$ = − 191° C.) | |
|---|---|---|---|
| $P$ (mm.). | Dielectric Constant. | $P$ (mm.). | Dielectric Constant. |
| 200 | 1.000502 | 200 | — |
| 400 | 1.001002 | 400 | 1.000483 |
| 600 | 1.001472 | 600 | 1.000730 |
| 760 | 1.001887 | 760 | 1.000928 |
| Methane ($T$ = − 154° C.) | | Carbon Dioxide (− 73° C.) | |
| 200 | — | — | — |
| 400 | 1.00114 | 400 | 1.000727 |
| 600 | 1.00172 | 600 | 1.00109 |
| 760 | 1.00212 | 760 | 1.00141 |

This expression is substantiated by the researches of Riegger.[9]

For the higher pressure range, the dielectric constant continues to be a distinct function of the testing pressure:

TABLE V (FIGURE 3).

*The Effect of High Pressure Application on the Dielectric Constant.*

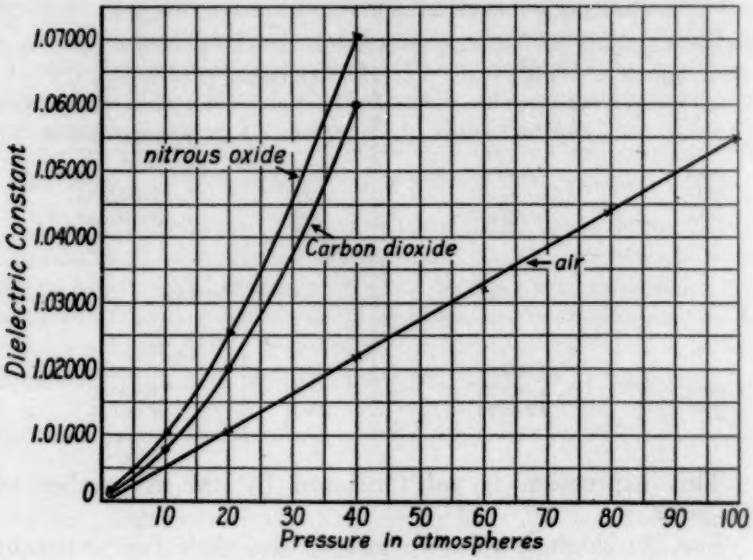
| Air (19° C.). | | Carbon Dioxide (15° C.). | |
|---|---|---|---|
| Pressure in Atmospheres. | Dielectric Constant. | Pressure in Atmospheres. | Dielectric Constant. |
| 1 | 1.00059 | 1 | 1.00098 |
| 20 | 1.0108 | 10 | 1.008 |
| 40 | 1.0218 | 20 | 1.020 |
| 60 | 1.0330 | 40 | 1.060 |
| 80 | 1.0439 | | |
| 100 | 1.0548 | | |

Nitrous Oxide (15° C.).

| Pressure in Atmospheres. | Dielectric Constant. |
|---|---|
| 1 | 1.001 |
| 10 | 1.010 |
| 20 | 1.025 |
| 40 | 1.070 |

[9] H. Riegger, *Ann. der Physik*, 59, 753 (1919).

FIG. 3.




The effect of high pressure on the dielectric constant.

The physical and chemical effects of pressure increase must be considered in the study of dielectric constant. Association or liquefaction phenomena may tend to alter the expected changes (Fig. 3).

### THE EFFECT OF FREQUENCY ON THE DIELECTRIC CONSTANT OF GASES.

Under ordinary conditions of measurement, the dielectric constant of gases is not greatly affected by changes in frequency. The frequency of the applied field ($\omega$) is usually so small in comparison to that characteristic of the molecule under test ($\omega_0$) that the ratio $\omega/\omega_0$ appearing in the modified Debye [10,11] equation is negligible (see part I).

E. C. Fritts [12] gives the following data for nitrogen gas at 0° C. and 760 mm. pressure, showing the lack of dependence of dielectric constant on frequency for wave-lengths ranging from 393 to 1,230 meters.

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[10] P. Debye, "Handbuch der Radiologie" (Marx), Vol. VI, 597–667, Leipzig (1925).

[11] P. Debye, *Ber. physik. Ges.*, 15, 777 (1913).
J. H. Tumners, Diss. Utrecht (1914).

[12] E. C. Fritts, *Phys. Rev.*, 23, 345 (1924).

| | |
|---|---|
| 393 meters | 1.000545 |
| 593 " | 1.000550 |
| 1,230 " | 1.000556 |

With air, tested under 760 mm. pressure at 0° C., the dielectric constant was found by Gill [13] to be independent of wave-length used.

| Wave-length. | Dielectric Constant. |
|---|---|
| 920 | 1.000658 |
| 1,300 | 1.000654 |
| 1,760 | 1.000654 |
| 4,000 | 1.000653 |

### THE EFFECT OF VOLTAGE.

The dielectric constant of gases appears almost independent of voltage stress, ionization effects being avoided. Thus, in the preceding data, Gill [13] found no change in the dielectric constant for a five fold increase in voltage field strength. Malsch [14] using a modification in the technique of Wein (*Physik Z.*, 23, 399 (1922)) has reached similar conclusions. Measurements on water, glycerol, and ethyl ether, using heavily damped oscillation at frequencies of the order of $10^3$ kilocycles, indicate no change in dielectric constant with varying field strengths. Well treated commercial dielectrics show a similar dielectric constant stability under changing voltage stress.

### THE EFFECT OF THE MAGNETIC FIELD ON THE DIELECTRIC CONSTANT OF GASES.

Weatherby and Wolf [15] have found no effect for the molecular symmetrical gases helium, oxygen and air with applied magnetic fields of 10,000 gauss. Neither was any effect obtained by Mott-Smith and Daily working with hydrogen chloride and nitric oxide under magnetic fields of 4,800 gauss at room temperature under pressures from 2 to 40 cm. of mercury.[16] J. J. Weigle [17] has obtained data in agreement with the results of Mott-Smith and Daily. From the basis of classical statistical dynamics, Weigle shows that

[13] E. W. Gill, *Rad. Rev.*, 2, 450 (1921).
[14] J. Malsch, *Ann. Physik*, 84, 841 (1927).
[15] B. B. Weatherby and A. Wolf, *Phys. Rev.*, 27, 69 (1926).
[16] L. M. Mott-Smith and C. R. Daily, *Phys. Rev.*, 28, 976 (1926).
[17] J. J. Weigle, *Phys. Rev.*, 29, 362 (1927).

the average electric moment in the direction of the electric field is unaffected by the presence of a magnetic field.

### THE EFFECT OF CHANGING STATE (GAS TO LIQUID TO SOLID).

The magnitude of the dielectric constant depends upon the number of molecules per unit volume and their orientation in the electric field applied. Molecular orientation depends upon freedom of motion of the polar particle. With gases this condition usually obtains. In liquids, however, the orientation may be greatly restricted. With the formation of the solid state, orientation may become impossible. Liquid substances possessing dipole structures normally show a great drop in dielectric constant on solidification after which but little change is observed with further decrease in temperature.[18,19]

The effect of changing state is summarized in Tables VI and VII for a number of typical gaseous, liquid and solid componuds covering a wide range in dielectric constant. (Examples are also given in Fig. 4.)

TABLE VI

*The Effect of Changing State; Gas to Liquid.*

| Substance. | Dielectric Constant Gas. | Dielectric Constant Liquid. |
|---|---|---|
| Carbon dioxide | 1.00098 (30° C.) | 1.32 (30° C.) |
| Benzene | 1.0027 (85° C.) | 2.17 (80° C.) |
| Carbon tetra chloride | 1.00273 (86.8° C.) | 2.10 (76° C.) |
| Chloroform | 1.00341 (68.8° C.) | 4.23 (61° C.) |
| Ethyl alcohol | 1.0065 (100° C.) | 17.3 (78° C.) |
| Water | 1.0070 (18° C.) | 81.07 (18° C.) |

TABLE VII.

*The Effect of Changing State; Liquid to Solid.*

| Substance. | Dielectric Constant Liquid. | Dielectric Constant Solid. |
|---|---|---|
| Hydrogen | 1.241 (− 258.4° C.) | 1.248 (− 259° C.) |
| Nitrogen | 1.44 (− 208.0° C.) | 1.46 (− 210° C.) |
| Paraffin wax | 2.15 (60° C.) | 2.10 (50° C.) |
| Diethyl ether | 8.95 (− 108° C.) | 2.1 (− 120° C.) |
| m-dinitro-benzene | 20.65 (90° C.) | 2.85 (25° C.) |
| Methyl alcohol | 60 (− 95° C.) | 3.07 (− 98° C.) |
| Ethyl alcohol | 50 (− 110° C.) | 2.70 (− 120° C.) |
| Water | 81 (18° C.) | 2.85 (− 5° C.) |

[18] H. Isnardi, *Physik Z.*, 22, 230 (1921); *Z. Physik*, 9, 153 (1922).

[19] P. Lertes, *Z. Physik*, 6, 257 (1921).

### THE EFFECT OF TEMPERATURE ON THE DIELECTRIC CONSTANT OF LIQUIDS AND SOLIDS.

As for gases, so for liquids, the effect of temperature change on the dielectric constant is least effective on those substances of an electrically symmetrical molecular structure. The effect of temperature on the dielectric constant of solid compounds is not strongly marked even in materials possessing highly developed polar structures.

Nitrogen and hydrogen show but little effect of temperature over the range that has been investigated: [20,21]

TABLE VIII (FIGURE 4).

*The Effect of Temperature on the Dielectric Constant of Non-Polar Molecules.*

| Nitrogen. | | Hydrogen. | |
|---|---|---|---|
| 76.5° K. | = 1.44 (liquid) | 20.33° K. | = 1.225 (liquid) |
| 74.8 | = 1.44 | 18.05 | = 1.234 |
| 66.70 | = 1.46 | 14.61 | = 1.241 |
| 63.9 | = 1.47 | 14.00 | = 1.248 (solid) |
| 61.9 | = 1.46 (solid) | 13.50 | = 1.224 |
| 59.9 | = 1.46 | 13.30 | = 1.212 |
| | | 13.20 | = 1.211 |

The effect of temperature on the dielectric constant of polar liquids is marked. Solidification with its resulting molecular fixation endows polar molecules with dielectric constant characteristics closely approaching those of the non-polar liquids.

TABLE X (FIGURE 4).

*Ethyl Ether (18).*

| ° C. | Dielectric Constant. |
|---|---|
| 18 | 4.389 liquid |
| 0 | 5.580 |
| − 56 | 6.703 |
| − 80 | 7.705 |
| −104 | 8.629 |
| −115 | 3.750 solid |
| −130 | 1.752 |
| −186 | 1.650 |

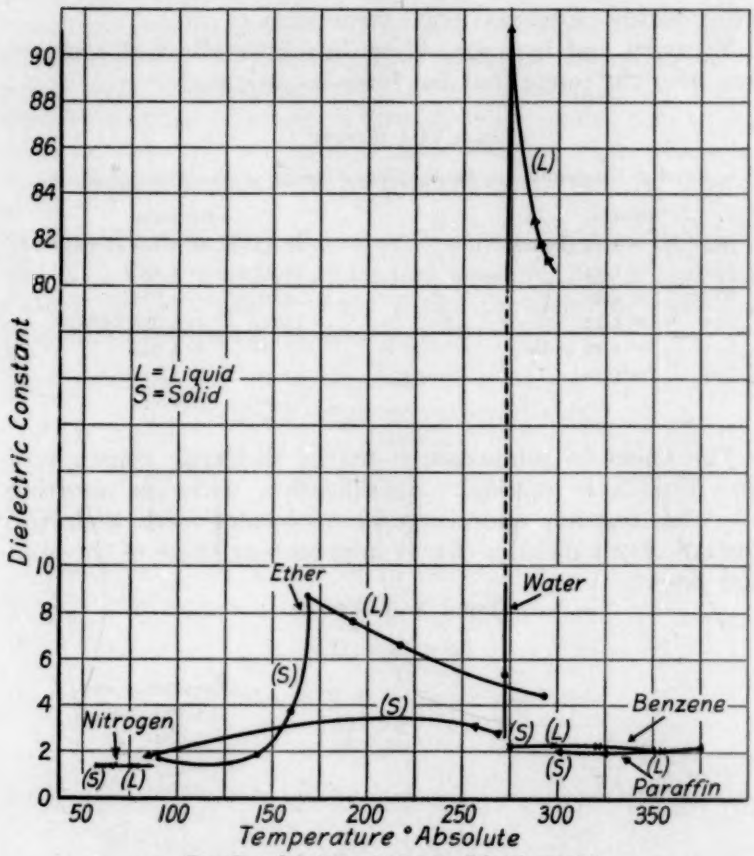
[20] L. Ebert and W. H. Keeson, *Verlag. Akad. Wetenschappen*, Amsterdam, 35, 875 (1926).

[21] M. Wolfke and H. K. Onnes, *Proc. Acad. Sci. Amsterdam*, 27, 627 (1924).

*Nitrobenzene.*

| °C. | Dielectric Constant. | |
|---|---|---|
| 20 | 32 | (liquid) |
| 16 | 36 | |
| 4 | 3.8 | (solid) |
| − 5 | 3.4 | |
| −13 | 3.2 | |
| −30 | 3.1 | |

FIG. 4.




The effect of charging state on the dielectric constant.

As already mentioned, the effect of temperature change on the dielectric constant of polar liquids may give abnormal results due to association or dissociation phenomena. Glycerine [22] shows such behavior.

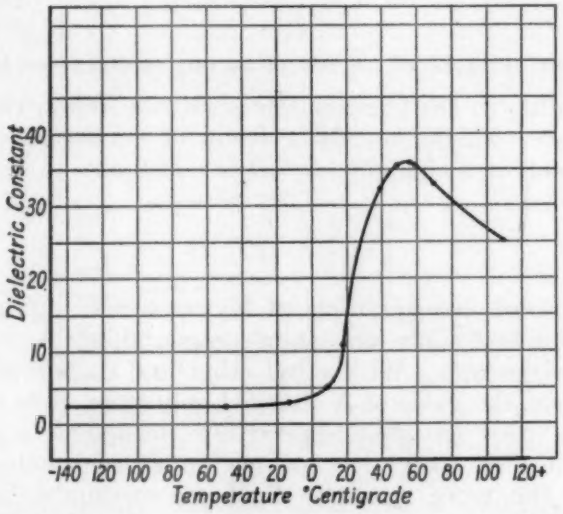
[22] R. Bock, *Zeit. f. Physik*, 130, 535 (1925).

TABLE XI (FIGURE 5).

*The Effect of Temperature on the Dielectric Constant of Glycerine (22) (Wave-length 1.36 meters).*

| Temperature ° C. | Dielectric Constant. |
|---|---|
| −140.6 | 2.8 (solid) |
| − 48.8 | 2.8 |
| − 12.8 | 3.1 |
| 8.6 | 5.0 |
| 16.2 | 10.9 (liquid) |
| 39.6 | 31.9 |
| 50.0 | 35.8 |
| 56.6 | 35.8 |
| 59.7 | 35.6 |
| 70.0 | 33.0 |
| 110.0 | 29.8 |

FIG. 5.




The effect of temperature on the dielectric constant of glycerine. Wave-length 1.36 m.

THE EFFECT OF FREQUENCY ON THE DIELECTRIC CONSTANT OF LIQUIDS.

The effect of low frequency variation on the dielectric constant of liquid polar and non-polar molecules is small. This necessarily results from the tenets of the completely developed Debye equation (part I) in which frequency appears only as the ratio $\omega/\omega_0$ necessarily negligible over the usual testing frequencies because of the large value of the

characteristic frequency ($\omega_0$) as compared to that of the frequency of the applied field ($\omega$).[23]

TABLE XII.

*The Effect of Frequency on the Dielectric Constants of Polar Liquids.*

| Water (18° C.) Wave-length (meters). | Dielectric Constant. | Glycerine (17° C.) Wave-length (meters). | Dielectric Constant. |
|---|---|---|---|
| 34.2 | 82.85 | 33.2 | 50.05 |
| 35.9 | 82.25 | 25.5 | 51.0 |
| 41.0 | 81.45 | 42.6 | 49.05 |
| 45.3 | 81.25 | 47.3 | 49.5 |
| 46.6 | 78.4 | 74.0 | 52.15 |
| 61.6 | 81.05 | 83.3 | 52.15 |
| 70.6 | 82.7 | 91.2 | 51.95 |
| 80.5 | 80.2 | 98.0 | 50.9 |
| 103.0 | 82.65 | 103.0 | 53.05 |
| | | 123.0 | 49.85 |
| | | 152.0 | 52.85 |

**THE EFFECT OF PRESSURE ON THE DIELECTRIC CONSTANT OF LIQUIDS.**

According to the Clausius-Mossotti researches, the effect of pressure, which manifests itself in increased density, should result in a changing dielectric constant:

$$\frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{1}{D} = k.$$

The recent investigations of Kyropoules [24] indicate that this relation holds only for certain compounds of relatively low dielectric constant. With ethyl ether and carbon disulfide, for instance, the value of $K$ changed only from .7380 to .7287 and from .2807 to .2788 respectively throughout a pressure range from 1 to 3,000 kilograms per square centimeter.

With the more strongly dipolar compounds, however, increased pressures gave a material decrease in the value of the Clausius-Mossotti expression.

Numerous other researches have been carried out in the field of high pressures. Grenacher [25] has observed that the pressure coefficient of dielectric constant assumes greater importance for the polar than the non-polar liquids. In an

[23] R. T. Lattey, *Phil. Mag.*, 41, 829 (1921).

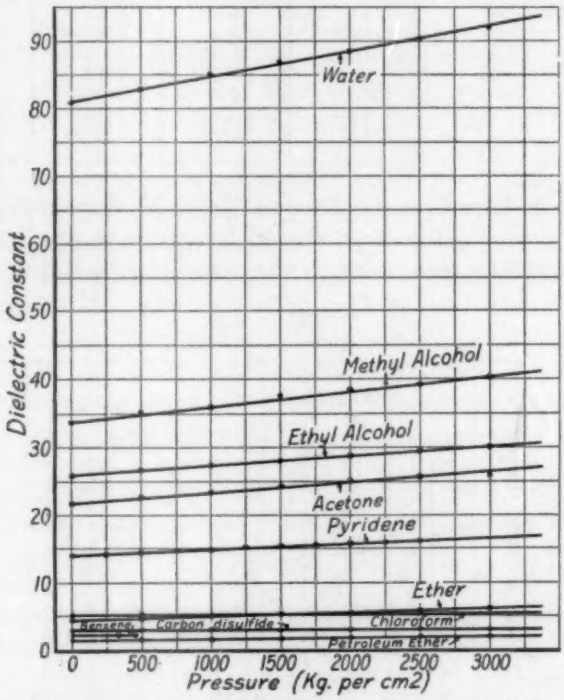
[24] S. Kyropoules, *Z. für Physik*, 40, 507 (1926).

[25] M. Grenacher, *Ann. d. Physik*, 77, 138 (1925).

investigation covering only the non-polar compounds, such as hexane, benzene and carbon disulfide, Waibel [26] has observed an approximate quadratic relation between applied pressure and resultant dielectric constant.

$$\epsilon = \epsilon_0(1 + ap + bp^2). \qquad \text{VII}$$

FIG. 6.




The effect of pressure on the dielectric constant of polar and non-polar compounds.

The work of Francke [27] in the field of non-polar liquids indicates a weakly increasing dielectric constant with pressure.

The effect of pressure on the dielectric constant as determined by Kyropoules for materials representative of a wide range of molecular moment is summarized in Table XIII and Fig. 6.

[26] F. Waibel, *Ann. d. Phys.* 72, 161 (1923).

[27] Charlotte Francke, *Ann. d. Phys.*, 77, 159 (1925).

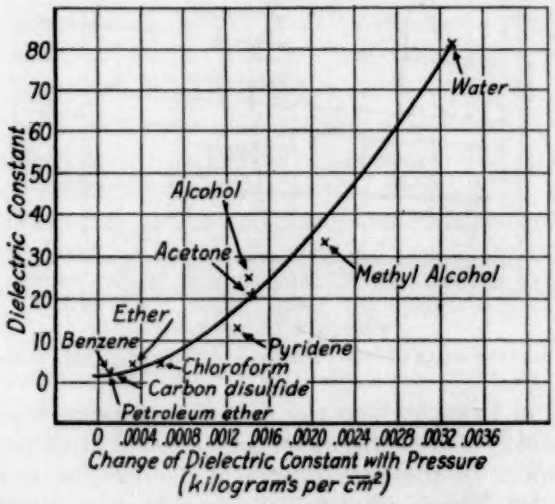
TABLE XIII.

*The Effect of Pressure on the Dielectric Constant.*

| Liquid. | Molecular Moment $\times 10^{18}$. | Dielectric Constant. | Pressure Range (Kg./cm.$^2$). | $\frac{\Delta\epsilon}{(Kg./cm.^2)}$. |
|---|---|---|---|---|
| Carbon disulfide | 0 | 2.64 | 1–3000 | .0001 |
| Carbon tetra chloride | 0 | 2.24 | 1–1000 | .0001 |
| Benzene | 0 | 2.28 | 1–400 | .0001 |
| Petroleum ether | 0 | 1.87 | 1–3000 | .00007 |
| Chloroform | 1.0 | 4.95 | 1–3000 | .0003 |
| Ethyl ether | 1.37 | 4.3 | 1–3000 | .00053 |
| Pyridine | 1.2 | 13.93 | 1–2500 | .0013 |
| Acetone | | 21.5 | 1–3000 | .0014 |
| Ethyl alcohol | 1.7 | 25.7 | 1–3000 | .0014 |
| Methyl alcohol | 1.7 | 33.79 | 1–3000 | .0021 |
| Water | 1.7 | 80.79 | 1–3000 | .0033 |

Figure 7, based on the data of Table X, demonstrates the rapidly increasing effect produced by pressure application in passing from the non-polar to the polar compounds.

FIG. 7.




The dielectric constant-pressure relation. (Based on Fig. 6.)

DIELECTRIC CONSTANT OF MIXTURES.

In the study of dielectric constant it must always be borne in mind that association phenomena may at times play a

dominating rôle. This is especially true in the consideration of mixtures. A complete discussion of mixture phenomena lies beyond the scope of this paper. For a detailed review of the problem the reader is referred to the recent publication by H. H. Lowry,[28] who presents the problem from the standpoints of (*a*) liquid-liquid mixtures, (*b*) electrolytic solutions, (*c*) non-electrolytic solutions, (*d*) colloidal solutions and (*e*) mixtures showing a high degree of heterogeneity, such as powders in air.

It has been the aim of repeated researches to establish a definite relation between the dielectric constants of the components and the dielectric constant of the resulting mixture in order that the value of one of the factors may be calculated from the known values of the others. These researches have included a study of such physical characteristics as refractive index, density, specific heat, etc. However, no satisfactory generalization has been obtained. Formulæ which have been suggested apply only with such special limitations that they are of but little value. They are all predicated on the fact that the capacities involved are directly additive and overlook the influence which the molecular components of the mixture may have upon one another. The presence of the strong electrostatic field surrounding polar molecules cannot be neglected in any study of the dielectric properties of a mixture of which they may be one of the component parts. It is only in the case of those materials with electric moments approaching zero that mutual molecular effect may be neglected. For this reason the various formulæ suggested for mixtures have been found to apply most accurately in those cases where only low dielectric constant materials are involved.

#### LIQUID-LIQUID SOLUTIONS WITH ADDITIVE CHARACTERISTICS.

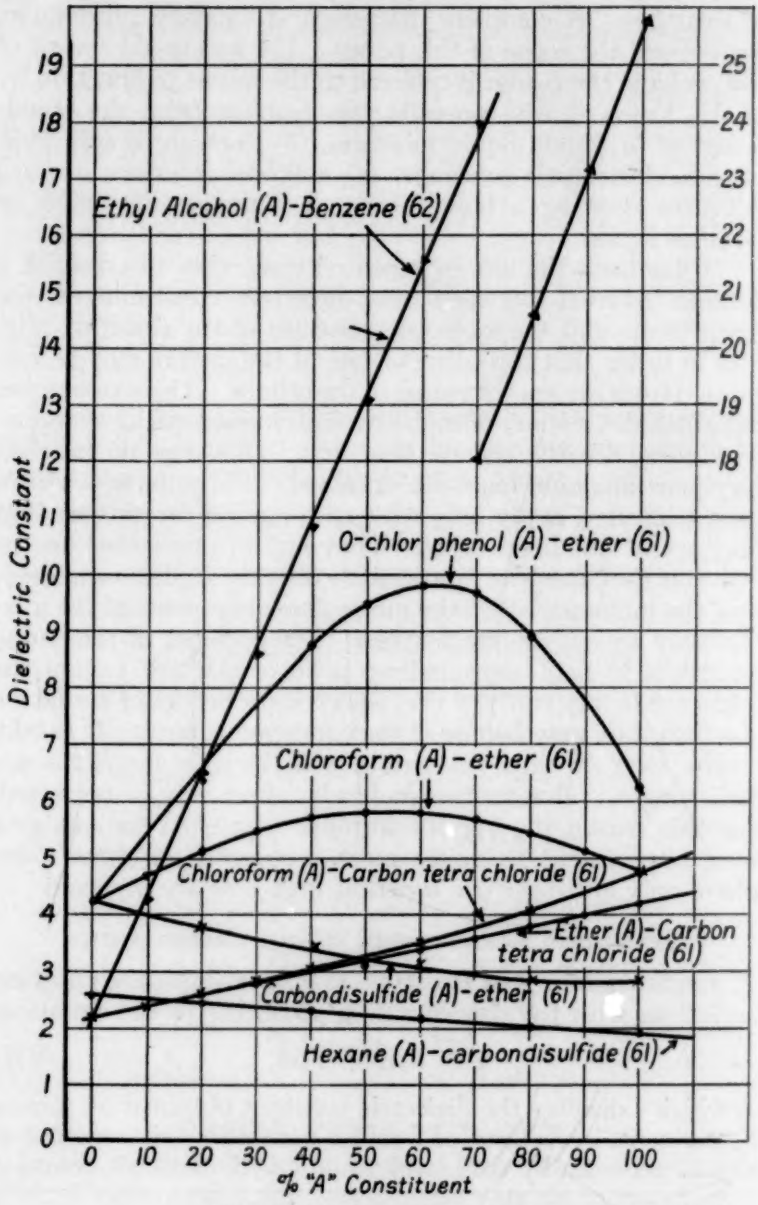
Liquid mixtures of this type will show dielectric constant variations with the concentration according to the equation:

$$\epsilon = V_1\epsilon a + V_2\epsilon b, \qquad \text{VIII}$$

in which $\epsilon$ denotes the dielectric constant obtained on mixing $V_1$ per cent. by volume of liquid $a$ with dielectric constant $\epsilon a$ and $V_2$ per cent. by volume of liquid $b$ with dielectric constant

[28] H. H. Lowry, JR. FRANK. INST., 203, 413 (1927).

FIG. 8.

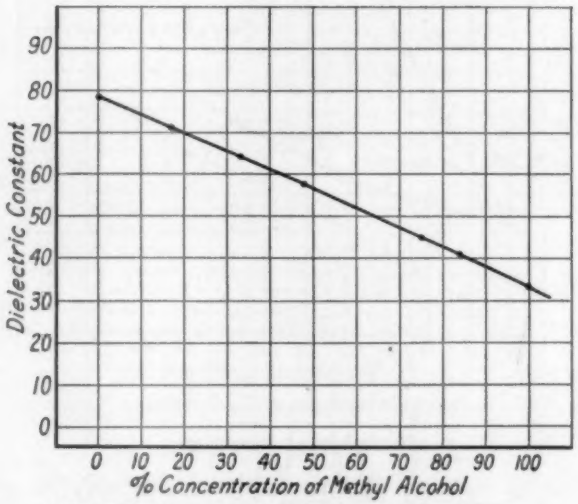



The dielectric constant of liquid mixtures.

*eb*. Mixtures of this type most closely obey the various formulæ suggested. Figures 8 and 9 illustrate the following combinations of the type:

Carbon tetra chloride and diethyl ether,
Carbon disulfide and hexane,
Ethyl alcohol and benzene,
Methyl alcohol and water.

FIG. 9.




The dielectric constant of methyl alcohol-water mixtures.

**LIQUID-LIQUID SOLUTIONS WHOSE CHARACTERISTICS ARE NOT ADDITIVE.**

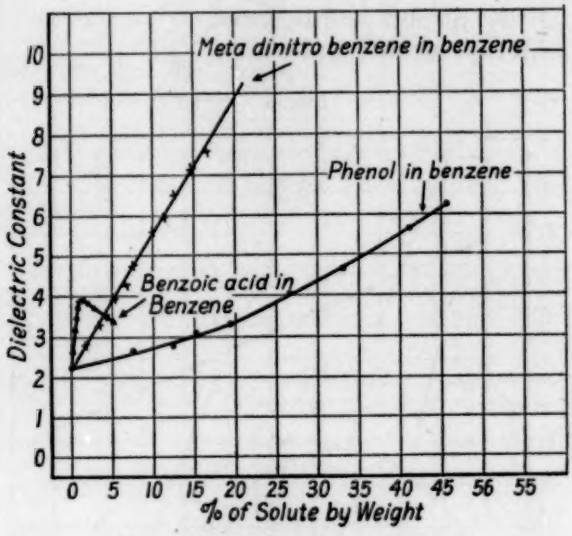
Materials of this group do not follow the characteristics of equation VIII and vary widely from the various formulæ of Lorenz-Lorentz, Silberstein, Clausius-Mossotti, etc. Mixtures showing non-additive characteristics of this type generally involve at least one constituent containing a molecular dipole whose pronounced electrostatic field leads to association effects. Such mixtures are also illustrated in Fig. 8.

Chloroform and carbon tetra chloride,
Chloroform and diethyl ether,
Ortho chlor phenol in diethyl ether,
Carbon disulfide in diethyl ether.

SOLID IN LIQUID SOLUTIONS (NON-ELECTROLYTIC).

Non-electrolytic solutions of solids in liquids behave like those of liquids in liquids [29] (Figs. 10 and 11).

FIG. 10.




The dielectric constant of benzene solutions.

ELECTROLYTIC SOLUTIONS.

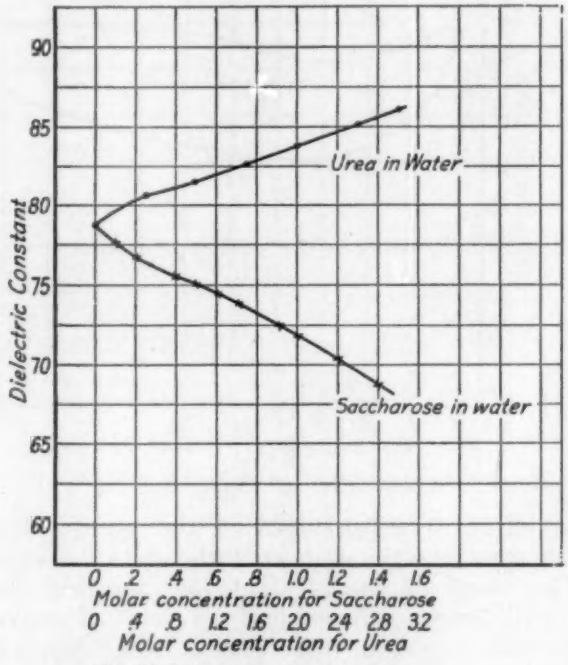
A general survey of the field of electrolytic solutions indicates that the Debye theory of dielectrics is satisfied, qualitatively at least. Further detailed researches may be expected to strengthen its application. Investigations in this field, however, are difficult due to the highly conducting characteristics shown. This is minimized by the use of the higher testing frequencies.

A detailed discussion of electrolytic solutions lies beyond the scope of this paper. It is of importance to note, however, that the effect of applied voltage, negligible in the testing of non-electrolytic mixtures, assumes considerable importance in the study of electrolytic solutions. With a frequency of 50 cycles Furth [30] has found that the dielectric constant of sodium

[29] R. Furth, *Ann. d. Physik*, 70, 75 (1923).
[30] R. Furth, *Physik Z.*, 25, 676 (1924).

chloride solution in water is dependent on the testing potential. This is illustrated in Fig. 12. With both testing voltages shown, the minimum dielectric constant is found at approximately the same molecular concentration.

FIG. 11.



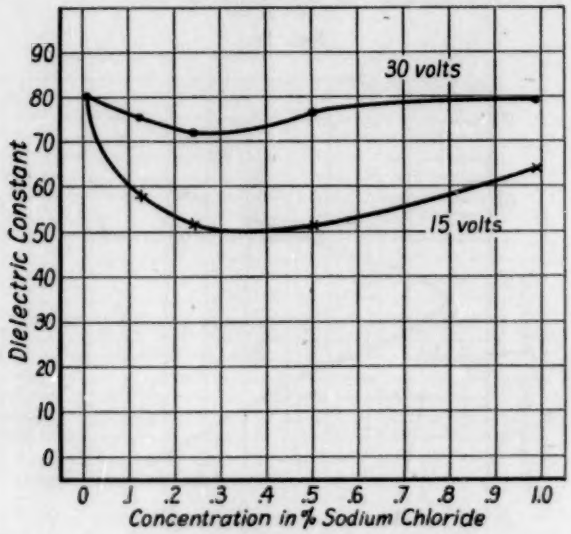

The dielectric constant of water solutions.

### THE EFFECT OF MOLECULAR STRUCTURE.

Since most inorganic substances are solids, insoluble in non-polar liquids, organic compounds lend themselves more readily to investigation. Groups which, in inorganic substances, tend to form ions, are generally found on the basis of the hypothesis of molecular structure to give rise to unsymmetrical arrangements of charges in organic molecules, with resulting increase in dielectric constant. A general review of the more common classes of organic compounds is given in Fig. 13, from which it will be observed that, as the special chemical characteristics of each class are decreased by

increasing molecular weight, so also is the characteristic dielectric constant.

FIG. 12.



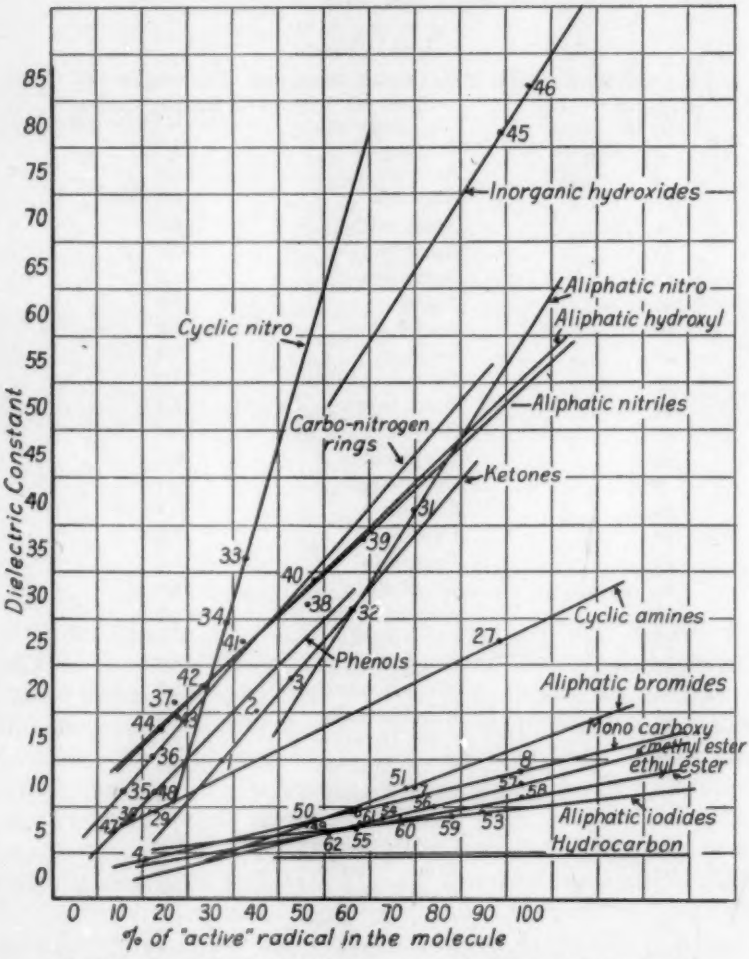

The effect of voltage on the dielectric constant of sodium chloride in water solution.

The effect of substitution in the organic hydrocarbon molecule may be estimated from the data presented in Fig. 13. The slope of the straight line showing the relation between dielectric constant and per cent. of active group in the molecule serves as the basis of this comparison. The groups illustrated are arranged as follows:

| Group. | Slope. |
|---|---|
| Cyclic nitro | 3.31 |
| Inorganic hydroxyl | 1.56 |
| Aliphatic nitro | 1.43 |
| Carbonyl (ketonic) | 1.15 |
| Phenolic hydroxyl | .97 |
| Alcoholic hydroxyl | .93 |
| Nitrile | .90 |
| Cyclic amino | .47 |
| Bromide (organic) | .34 |
| Methyl or ethyl ester | .24 |
| Carboxyl | .23 |
| Iodide (organic) | .21 |
| Alkyl, phenyl, etc. | 0 |

The compounds upon which this tabulation is based and which are illustrated in Fig. 13 are listed in Table XIV.

FIG. 13.




The dielectric constant as affected by the active radical present in the molecule.

The arrangement of the various substituent groups in the preceding tabulation rates them according to their effect on the electrical symmetry of the parent molecule. Further study of this rating also reveals the close relationship existing

between substitution polarity effects and chemical reactivity. The fact that polar molecules, as a result of their more intense electrostatic envelope, also act strongly as promoters of certain chemical reactions has already been noted.

TABLE XIV.

*The Dielectric Constants of the Organic Compounds illustrated in Fig. 13.*

| Number in Figure 13. | Compound. | Dielectric Constant at Room Temperature |
|---|---|---|
| 7 | Acetic acid | 9.5 |
| 3 | Acetone | 21.0 |
| 27 | Ammonia | 25.0 (liquid) |
| 44 | Amyl alcohol | 15.8 |
| 50 | Amyl bromide | 6.0 |
| 12 | Amylene (*n*) | 2.2 |
| 29 | Aniline | 7.0 |
| 16 | Anthracene | 2.2 |
| 26 | Benzene | 2.2 |
| 37 | Benzyl cyanide | 18.7 |
| 49 | Brom benzene | 5.5 |
| 43 | Butyl alcohol (*n*) | 17.0 |
| 54 | Butyl iodide (*n*) | 6.1 |
| 5 | Butyric acid (*n*) | 3.0 |
| 22 | Cumene | 2.2 |
| 18 | Cymene | 2.5 |
| 11 | Decane (*n*) | 2.2 |
| 14 | Decylene (*n*) | 2.2 |
| 1 | Diethyl ketone | 12.5 |
| 59 | Ethyl acetate | 6.4 |
| 41 | Ethyl alcohol | 25.0 |
| 24 | Ethyl benzene | 2.2 |
| 51 | Ethyl bromide | 9.4 |
| 61 | Ethyl butyrate | 5.5 |
| 38 | Ethyl cyanide | 29.0 |
| 58 | Ethyl formate | 8.5 |
| 2 | Ethyl-methyl ketone | 18.0 |
| 60 | Ethyl propionate | 6.0 |
| 62 | Ethyl valeriate | 4.5 |
| 8 | Formic acid | 11.0 |
| 52 | Hydriodic acid | 7.7 |
| 9 | Hexane (*n*) | 2.2 |
| 46 | Hydrogen peroxide | 84.0 |
| 47 | Hydrocymene | 5.5 |
| 55 | Iodo benzene | 5.0 |
| 19 | Isobutyl benzene | 2.2 |
| 21 | Mesitylene | 2.2 |
| 56 | Methyl acetate | 7.5 |

TABLE XIV—*Continued.*

| Number in Figure 13. | Compound. | Dielectric Constant at Room Temperature. |
|---|---|---|
| 40 | Methyl alcohol | 31.5 |
| 39 | Methyl cyanide | 36.0 |
| 57 | Methyl formate | 10.0 |
| 53 | Methyl iodide | 7.0 |
| 17 | Naphthalene | 2.5 |
| 33 | Nitrobenzene | 34.0 |
| 31 | Nitro methane | 39.0 |
| 34 | Nitro toluene | 27.0 |
| 32 | Nitro ethane | 28.5 |
| 10 | Octane | 2.2 |
| 13 | Octylene | 2.2 |
| 15 | Phenanthrene | 2.2 |
| 48 | Phenol | 9.0 |
| 6 | Propionic acid | 7.0 |
| 42 | Propyl alcohol | 20.0 |
| 20 | Propyl benzene | 2.2 |
| 36 | Pyridine | 13.0 |
| 35 | Quinoline | 9.0 |
| 4 | Stearic acid | 1.8 |
| 25 | Toluene | 2.3 |
| 30 | Toluidine (*o*) | 6.4 |
| 45 | Water | 79.0 |
| 23 | Xylene | 2.4 |

### THE DIELECTRIC CONSTANT—RESISTIVITY RELATION.

Considerable research must be carried out before the relation between dielectric constant and electrical resistivity can be definitely described. From data available, it appears that increased polarity leading to increased dielectric constant manifests itself as well in decreased resistivity. Resistivity values, however, are so markedly dependent on the absence of contamination that no great reliance can be placed on the results available. The effect of increased polarity acccompanying increased dielectric constant makes more pronounced the presence of ionizable impurities, thus tending to make the resistivity values for the higher constant materials still more uncertain. Electrode effects under D.C. voltages further complicate the situation.

The decreased resistivity accompanying increased dielectric constant is roughly illustrated in the data given in Table XV.

TABLE XV.

*Relation between Dielectric Constant and Resistivity.*

| Material. | Dielectric Constant. | Characteristic Resistivity (ohms per cm.³). |
|---|---|---|
| Benzene | 2.15 | $4.7 \times 10^{12}$ (100° C.) |
| Petroleum oils | 2.2 | $10.0 \times 10^{12}$ (100° C.) |
| Paraffin wax | 2.25 | $5.0 \times 10^{12}$ (100° C.) |
| Cottonseed oil | 2.9 | $.2 \times 10^{12}$ (100° C.) |
| Asphalt | 3.1 | $1.0 \times 10^{12}$ (100° C.) |
| Linseed oil | 3.3 | $.61 \times 10^{12}$ (100° C.) |
| China wood oil | 3.5 | $.08 \times 10^{12}$ (100° C.) |
| Castor oil | 4.3 | $.06 \times 10^{12}$ (100° C.) |
| Ethyl alcohol | 25.0 | $.3 \times 10^{6}$ (18° C.) |
| Methyl alcohol | 31.0 | $.14 \times 10^{6}$ (18° C.) |
| Water | 81.07 | $.5 \times 10^{6}$ (18° C.) |

# THE DISTRIBUTION AND VELOCITY OF THE CORROSION OF METALS.

BY

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In a lecture delivered at The Franklin Institute on February 14, 1929, a brief account was given of some recent researches conducted at Cambridge University, England, on the Corrosion and Passivity of Metals. Details of this work are recorded elsewhere.[1] The present paper is an attempt to summarize the main conclusions reached in the lecture, and then to suggest how the principles arrived at may be extended to the consideration of the Velocity of Corrosion.

*Distribution of Corrosion.*—As explained in earlier papers, oxide films are liable to occur on all metals which have been exposed to the air, even at ordinary temperature; the films are similar to those responsible for the beautiful interference colours that appear on metals heated in air, but are too thin to produce interference tints. Whilst in optical contact with the metal, these films are usually "invisible." They become visible, however, when separated from the reflecting basis. Such a separation may be brought about by a treatment designed to dissolve the metal, but to leave the oxide film unchanged; anodic treatment, and immersion in iodine solution, have both been used, in different cases, to undermine and isolate the film. A new method has recently been worked out by J. Stockdale and the author for obtaining specimens of the film mounted flat on a support. This consists in subjecting the specimen to a short anodic treatment in sodium chloride solution so that the film is loosened by the removal of the metal immediately below it, and then transferring the loose film by pressure to glass coated with nitrocellulose lacquer in a "tacky" condition. Details of the procedure will be published shortly.

[1] U. R. Evans, "The Corrosion of Metals," 1926 edition (Longmans, Green, New York; Arnold, London); *J. Chem. Society*, 1927, p. 1020; 1928, pp. 92, 111.

In general, oxide films of the kind described will not prevent corrosion altogether, but will tend to divert corrosion to the places where the film is weakest. Consider a piece of metal introduced into a sodium chloride solution. Before it enters the liquid a discontinuous oxide film exists over the surface. Immediately after the immersion, at each discontinuity in the oxide film, a struggle between two opposing changes commences. (1) The dissolved oxygen may begin to combine with the metal where it is exposed at the cracks in the film, thus repairing the discontinuities. (2) Anodic attack may set in, giving rise to the soluble chloride of the metal, thus undermining and loosening the skin, and causing the damage to spread. Where oxygen is deficient, this anodic attack will prevail; but at the places to which dissolved oxygen has ready access, the repairing action will generally prevail, and there will be no corrosion. The electric potential will be different according to the state of the repair of the film, and current will flow between the places of good and bad repair. The "aerated" places act as cathodes in the electrochemical process, whilst anodic corrosion will occur at points on the "unaerated" area, but it will only continue as long as oxygen is freely supplied to the cathodic places; if the supply of oxygen fails, polarization will set in and the current will die away, and consequently the corrosion at the anodic parts will cease. *Oxygen is thus needed for the corrosion, but the attack occurs at places relatively inaccessible to oxygen.* The *direct* effect of oxygen is to maintain a protective film; its *indirect* effect is to set up corrosion at the places where this film is weak, or absent.

When a plate of zinc is partly immersed in a vertical position in sodium chloride solution, corrosion commences at the weak points near the bottom (the portion least accessible to oxygen), and along the cut edges, or places subjected to bending, since the internal stresses left by the cutting, or bending, operation keep cracking the film; it may also set in at surface defects, or at the sites of pores, the interiors of which are less accessible to oxygen than other parts of the metal at the same horizontal level. The zinc chloride produced at the anodic points reacts with the sodium hydroxide produced on the cathodic area, yielding a precipitate of zinc

hydroxide which flows down from the original anodic spots, blanketing the surface, and screening it from repairing oxygen. The film present on the portion thus screened falls into bad repair, and the anodic attack, which was originally confined to a few weak points, gradually becomes general; finally only the portion quite close to the water level remains cathodic and free from corrosion, and almost all the rest of the surface suffers anodic attack. If iron is used in the experiment instead of zinc, the screening effect is more effectual, because here the primary anodic product, ferrous chloride, reacts with the primary cathodic product, sodium hydroxide, to yield ferrous hydroxide, which is a chemical absorbent of oxygen, being oxidized to a mixture of ferroso-ferric and ferric hydroxides, known as "rust"; thus the extension of the localized corrosion into general corrosion occurs very readily. On the other hand, on aluminum, the corrosion tends to remain slow and localized for a long time, because here the film is of a very protective character, not easily destroyed by undermining, and capable of being kept in repair by a very low concentration of oxygen. Alloys containing chromium, such as "stainless steel," also become covered with a highly "protective" skin, which is kept in repair by a very low concentration of oxygen, and which under favorable circumstances may prevent corrosion altogether.

The variations in the protective character of different oxides may depend on several circumstances: (1) If the metal can combine rapidly with oxygen, it may be expected that repairs will be effected readily; aluminum and chromium have high affinities for oxygen; (2) If the oxide is very impermeable to oxygen, it will exclude oxygen from the metal below it whilst it is still extremely thin, and will therefore cease to thicken further; a thin film is less liable to crack than a thick film, other things being equal. The oxide film on stainless steel is thinner than that on pure iron, and is certainly more protective; (3) If the oxide is mechanically strong, it is more likely to resist cracking through applied stresses; strength and stoutness in the metallic basis are also likely to militate against cracking.

It is not surprising that with some metals, the corrosion soon spreads out and becomes general, whereas on others it

remains local, whilst others again may resist attack altogether. But the behaviour depends on the conditions. Steel placed in a stagnant saline water tends to become blanketed with rust, and the corrosion spreads out over the parts from which loose rust blanket excludes the supply of oxygen and soon becomes fairly general. But if the water is in rapid motion, the corrosion remains localized, because the loose rust is not allowed to spread over the surface, but is swept away by the water current; furthermore the motion ensures a good supply of repairing oxygen to the main part of the surface. At the "weak points" rapid corrosion continues, producing rather deep pits, each covered with a blister of membranous rust. The corrosion is often intense, because the supply of dissolved oxygen to the large cathodic areas is rapid, whilst the attack, being concentrated on the relatively small anodic areas, digs rapidly down into the metal. The inclination of the surface is also important. On zinc, partly immersed in a *vertical* position, the attack tends to spread downwards and outwards and gradually to become fairly general, as already explained; with *horizontal* specimens, fully immersed, the attack is slower and may remain more localized, producing pits.

It is convenient to distinguish between (1) cases where corrosion remains *localized* and *slow*, and (2) those where it spreads out and becomes *general* and *rapid*. But it must be remembered that intermediate cases exist. There are some strange contrasts between the two types of attack. Where the protective character of the skin keeps the action localized, the presence of chlorine ions which can penetrate weak points in the skin impervious to sulphate ions, greatly increases the rate of corrosion; thus chloride solutions are more corrosive than sulphate solutions. In cases where the corrosion has spread out, giving a large anodic area, the penetrating power of the anion is of very little importance, and a sulphate solution may produce as rapid attack as a chloride solution. But the most striking difference between the two types is the behaviour at the water-line. Given uniform concentration of oxygen, the film is least protective at the water-line, where it may leave the metallic surface and cling to the air-metal interface. Thus a slowly corroding metal like aluminum, if attacked at all, is frequently pitted most severely along the

water-line. But with a rapidly attacked metal (if the liquid is stagnant) the rapid corrosion uses up oxygen very quickly, and the film is kept in best repair at the places most accessible to oxygen—that is, at and near the water-line; iron immersed in a sodium chloride solution suffers general corrosion over a large area a little way below the water-line, but at the water level itself and immediately below it, the metal remains bright and unchanged for some time. If by motion of the solution, the oxygen-concentration is rendered uniform, water-line attack on iron may be met with. Even in stagnant liquids the corrosion of iron may occur along the water-line, if the conditions are altered so that the total corrosion becomes slow; for in such a case the oxygen-consumption is small, and the oxygen-concentration is likely to remain fairly uniform. For instance, iron containing chromium builds a highly protective film, and if attack occurs at all, it is frequently concentrated along the water level. Again, ordinary iron (free from chromium) can suffer water-line attack, if "film-repairing" substances such as potassium chromate or sodium carbonate are present in the liquid. When a piece of iron is placed in a solution of sodium chloride containing a small amount of a "film repairer," the corroded area is far more restricted in extent than in a plain sodium chloride solution. With still greater amounts of "film-repairer," the lower corroded area may disappear altogether, but corrosion then sets in along the water-line, which in the absence of a film-repairer is the part most free from corrosion; with still larger amounts of film-repairers, corrosion may cease entirely. These film-repairers act in different ways. Some, like potassium chromate are oxidizing agents; others, like sodium carbonate, sodium hydrate or sodium phosphate, contain anions yielding sparingly soluble iron compounds, so that the effect of anodic action is to produce a sparingly soluble compound, thus automatically repairing weak points in the primary film. Although these compounds undoubtedly reduce the total corrosion, they also reduce the area undergoing corrosion, and thus, under some conditions, the *corrosion per unit area* may be increased; in other words the time needed to produce perforation may be reduced. Evidently the use of "film repairing" chemicals in the wrong places or in the wrong quantities, can be positively dangerous.

The principle of choosing a metal which will yield an insoluble body as the direct anodic product is one of the commonest ways of avoiding corrosion. Lead is an excellent metal for employment in sulphate solutions—owing to the very small solubility of lead sulphate; it is much more quickly attacked in nitrate or chloride solutions. In a sulphate solution, any incipient anodic attack will convert the surface layers of the lead to sulphate, and the film thus produced will automatically bring the anodic attack to a close. For success, the sparingly soluble body must be the *primary* anodic product, so that the surface of the metal shall be converted to the protective substance, *in situ*. The formation of a sparingly soluble body as a *secondary* product does not, in general, prevent attack. Rust, for instance, is a secondary product formed in the corrosion of iron; the exact nature of the rusting reaction will vary with the nature of the water, but in all cases, the rust is a precipitate formed by secondary changes from the soluble anodic products. It will not, in general, put a stop to corrosion, unless the whole surface becomes blanketed, so as to shut off oxygen completely from the metal.

*Velocity of Corrosion.*—As pointed out by Donker and Dengg,[2] the maximum E.M.F. available for the corrosion of a given metal is that of the cell Metal|Oxygen. But with liquids of high or medium conductivity, an E.M.F. of that value, if allowed to force current around the circuit connecting anodic and cathodic areas in accordance with Ohm's law, would produce a greater current (i.e. a greater rate of corrosion) than external conditions, such as the supply of oxygen, would permit. It therefore follows that the working E.M.F. must of necessity be reduced by "polarization." This may arise in two ways:

(*a*) The *anodic* potential may *rise* until it approaches the cathodic value, or

(*b*) The *cathodic* potential may *sink* until it approaches the anodic value.

As to which of these movements will be the more important depends upon the relative sizes of the anodic and cathodic

[2] K. J. Donker and R. A. Dengg, "Korrosion and Metallschutz," 1927, 3, 217, 241.

areas, upon the nature of the film, and upon the concentration of penetrating ions at the anode and that of oxygen at the cathode. In general, the conductivity of the liquid will only be a predominant factor in determining the rate of attack in very dilute solutions. Thus Bengough, Stuart and Lee, in the course of their extremely careful researches on the velocity of corrosion,[3] found that exceptionally pure water, having a very low conductivity, produced only a very slow attack on zinc, but that the addition of traces of almost any salt greatly increased the rate of corrosion.

Under conditions where the anodic attack is restricted to a few weak points in a film, the main part of the area being cathodic, it will be the anodic reaction which will control the velocity; the same is true of cases where the anodic attack is connected with a slow leakage through an otherwise impervious film. It will be known to those who have studied electrolytic cells fitted with aluminum anodes, and operated by an external E.M.F., that when a film is present on the anode, the amount of current passing is determined largely by the presence of traces of penetrating ions (notably chlorine ions) in the solution. Practically the whole of the E.M.F. applied will be banked up across the anodic film, the portion distributed over the liquid being insignificant. The same will be true, when the E.M.F. is generated internally by differences between the conditions prevailing at various parts of the surface of a piece of metal; the corrosion of aluminium, and of self-protecting alloys containing chromium, is largely determined by the presence of chlorides and other salts yielding penetrating anions.

With metals such as zinc, this will only be true if the conditions are such as to restrict the anodic areas. Bengough, Stuart and Lee have studied the corrosion of zinc under conditions favoring local attack ("pitting"), and find that at fairly low chloride concentration, the rate of attack is proportional to the chlorine ion concentration ($C_l$) existing at any moment. Thus the relation between the corrosion, ($y$) and the time ($t$) is

$$\frac{dy}{dt} = k_1 C_l,$$

[3] G. D. Bengough, J. M. Stuart and A. R. Lee, *Proc. Roy. Soc.* (*A*), 1927, 116, 425; 1928, 121, 88.

$k_1$ being a constant. But the chlorine ions are gradually removed from the liquid, in proportion to the amount of zinc hydroxide which has accumulated; probably the chloride is adsorbed on the zinc hydroxide. Thus

$$C_t = C_0 - k_2 y,$$

where $C_0$ is the original concentration of chlorine ions, and $k_2$ a constant.

Thus, the corrosion-rate falls off as the chlorine-ions are removed from the liquid,

$$\frac{dy}{dt} = k_1 (C_0 - k_2 y).$$

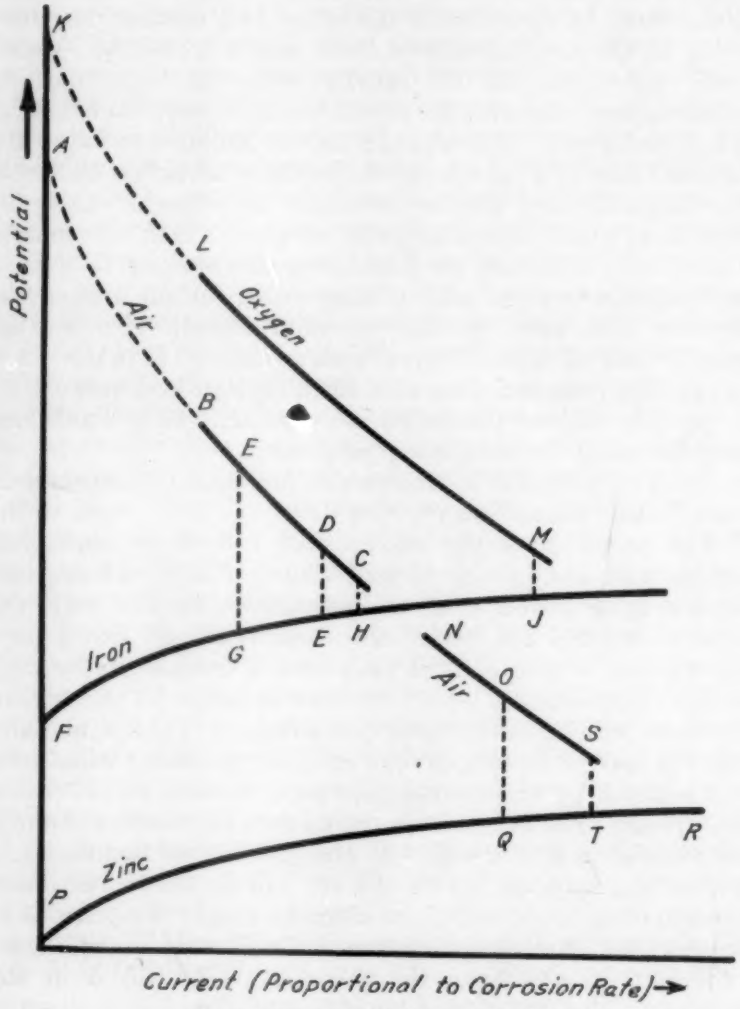
Bengough and his colleagues have found that such a relation holds very accurately for dilute potassium chloride solutions; they arrive at the equation by a slightly different theoretical argument, and reference should be made to their original papers, which represent a most important landmark in corrosion research. At high concentrations, the relation may no longer hold good, because the rate of oxygen supply to the cathodic areas is often insufficient.

In other cases, the rate of attack may be controlled by the happenings at the cathodic area; examples are provided by vertical specimens of iron or zinc partly immersed in chloride or sulphate solution. Here, as already explained, the descent of the hydroxides of iron or zinc from the original "weak points" causes the anodic areas to spread out rapidly, and any restriction of the changes due to the anodic reaction soon becomes unimportant.

The potential at the cathodic portion is a complicated function and is known to vary from point to point on the cathodic area. If the oxide-film were continuous and "perfect" in its excluding power, no doubt the potential at the aerated part would be that of an "oxygen electrode," and would be determined by the oxygen-concentration in the liquid. When current flows, the oxygen-concentration must diminish, reaching a steady state at which the fresh oxygen arriving by diffusion or convection exactly balances that consumed in the depolarizing action. Thus the potential will

drop rapidly as the current strength is increased, an idea suggested by the curve *ABC* (see Fig. 1). Actually the

FIG. 1.




Potential-current curves (Diagrammatic only).

tendency of the film to "leak" (allowing of slight anodic action even on the so-called cathodic area) will bring the

potentials measured by any ordinary method far below the "theoretical" values calculated on the assumption that the area is an "oxygen-electrode"; indeed it is doubtful whether it will ever be possible to realize experimentally the higher part of the curve (*AB*) shown in the figure as a broken line, since owing to the development of local anodic areas, the "measured" potentials fall off rapidly with the time, and no measurements of potentials or current have any real meaning. It is hoped shortly to start experiments designed to follow the "stable" part (*BC*) of the curve (shown as an unbroken line in the diagram), and also to ascertain, in different cases, the point *B*, at which the stable portion begins. Such information is absolutely necessary for calculating the working E.M.F. of the corrosion-process, and in some cases for calculating the effective resistance of the corrosion circuit. Up to the present time all that is known with certainty [4] is that

(1) The potential does sink when current is drawn off.

(2) The highest potentials are obtained under conditions most favorable for oxygen-replenishment.

(3) The potential is abnormally low near to cut edges or other "weak places" on the film.

The potential of the anodic area will move much less rapidly with increase of current (curve *FHJ*). Dengg and Donker have shown that the potential does rise with the current density, but under the conditions now being considered, the anodic area is large and a comparatively high current represents a small current density. The rate of corrosion will be determined (according to Faraday's Law) from the current flowing in the steady state where the E.M.F., duly reduced by the mutual approach of the lines *ABC* and *FHJ*, is just sufficient to force the current in question through the resistance of the cell. If the gas above the liquid is oxygen, the cathodic curve (*KLM*) will lie above the curve corresponding to air (*ABC*), the oxygen supply being better in the first case; thus assuming that the resistance of the circuit is the same in both cases, the reduction of the E.M.F. to the necessary value (*MJ*) will be obtained at a higher current density when oxygen is employed than when air is employed (*CH*); in other words, corrosion should be distinctly quicker

[4] U. R. Evans, *J. Chem. Society*, 1929, p. 92.

below an oxygen atmosphere than below an air atmosphere; this the author has found to be the case in his work on vertical, partly immersed specimens of steel. However, an increased oxygen-pressure will restrict the growth of the anodic areas, and thus alter the resistance of the circuit. In general, it may be said that increase of oxygen-pressure ought first to increase the corrosion-velocity until a maximum is reached, beyond which any further increase in the oxygen-pressure should diminish the rate of corrosion. On iron the maximum corrosion velocity seems to occur at an oxygen-pressure above the normal value; Schikorr's values [5] appear to place it at between 1 and 3 atmospheres; but it seems probable on theoretical grounds that with materials which build a highly protective oxide-film, the maximum may occur at a much lower pressure, and that such substances may actually be found to corrode more quickly under conditions where the supply of oxygen is restricted.

The effect of altering the concentration of the solution is usually smaller than the effect of altering the oxygen pressure. If, for instance, we dilute the solution with an equal part of water, thus roughly halving the specific conductivity, a comparatively small diminution in the current will suffice to double the E.M.F. (*CH* changing to *DE*). If we again halve the concentration, the necessary E.M.F. will be represented by *EG*. Evidently as we pass away from the place where the curves *AC* and *FH* intersect, the effect of conductivity on the current flowing under steady conditions, will (for any probable shape of the curves) become increasingly important. Thus conductivity will have comparatively little influence on the corrosion-rate at high ranges of concentration, but will be of vital importance at low ranges. This is found to be the case.

If we pass from iron to another metal, such as zinc, we get a different anodic curve (*PQR*), and thus (under the same conditions), the current flowing when the E.M.F. has reached the value (*ST*) necessary to force that current through the resistance will be different from that obtained in the case for iron. It is still uncertain whether the cathodic curve for zinc (*NOS*) will, under ideal conditions, be the prolongation of that for iron (*ABC*) or not. In general, however, it may be

[5] G. Schikorr, *Korr. Met.*, 1928, 4, 242.

expected that the corrosion-rate will increase as the normal electrode potential of the metal becomes more negative; [6] but this does not apply, of course, to metals, like aluminium, whose films are sufficiently protective to restrict the anodic reaction to very small areas.

The author recently made some determinations of corrosion velocity of vertical specimens in closed vessels under thermostatic conditions. For details, the original paper [7] must be consulted, but the following table gives the average of the most accurate measurements. The experiments of 4, 7, 14 and 24 hours duration alone have been used in calculating these averages; the shorter experiments are more liable to experimental errors, and in the longer ones the results are affected by certain complicating factors discussed in the original paper; during the period in question, the velocity was sufficiently constant to render the taking of an average legitimate. Each figure is the average of eight experiments or, in the two cases marked with an asterisk, of four experiments.

LOSS OF WEIGHT IN MILLIGRAMS PER HOUR OF VERTICAL SPECIMENS.

*Temperature 25.0° C. Immersed area 2.5 × 2.5 cms.*

| Liquid. | Mild Steel (0.26% C, 0.57% Mn). | Electrolytic Iron. | Zinc. |
|---|---|---|---|
| M/10 Potassium Chloride..... | 0.26 | 0.25 | 0.76 |
| M/10 Potassium Sulphate..... | 0.28 | 0.23 | 0.69 |
| M/10 Sodium Chloride..... | 0.27 * | — | — |
| M/10 Magnesium Sulphate..... | 0.07 * | — | — |

It will be noticed that with iron and steel, corrosion proceeds practically at the same rate in potassium sulphate as in potassium chloride solutions. With zinc, the chloride corrodes slightly more quickly than the sulphate, and this may be connected with the fact that on zinc the anodic attack is more localized than on iron. With aluminum corrosion

[6] The convention adopted is that potassium is assigned a negative value, and gold a positive value.

[7] U. R. Evans, *J. Chem. Society*, 1929, 111.

remains very much restricted to certain points, and chlorides are found to attack the metal distinctly more rapidly than sulphates, although no very accurate numbers are available.

The table shows that sodium chloride causes a similar rate of corrosion to potassium chloride, but that magnesium sulphate produces a much slower attack than potassium sulphate; this is because magnesium hydroxide, the cathodic product, is sparingly soluble, and separating out, hinders the diffusion of oxygen to the upper part of the specimen.

The numbers also display the rather surprising fact that electrolytic iron is attacked—under the conditions in question—almost as quickly as steel. This applies only to conditions of "differential aëration." Where the E.M.F. is set up by variation of oxygen-concentration, a second phase is not necessary in the generation of a corrosion current. Under conditions of uniform oxygen-concentration, the state of affairs is different, and, in distilled water at least, the electrolytic iron remains practically immune, whilst steel is rusted; the same distilled water will attack the same electrolytic iron quite readily under conditions of differential aeration, that is, when vertical specimens are partially immersed in the stagnant liquid.

Under the conditions considered hitherto, the velocity of corrosion is clearly a function both of the oxygen-supply and the nature of the metal; iron and zinc corrode at different rates. Under certain conditions, however, it is conceivable that all metals might corrode at the same rate. For instance, if specimens are placed at the bottom of extremely deep cylinders filled with water, down which dissolved oxygen is conveyed so slowly, that all the metals tested can use it up as quickly as it arrives, the corrosion (other than that connected with the displacement of free hydrogen) should be equivalent to the rate of supply of the oxygen, and should be independent of the nature of the metal, as such. This has a bearing on the long-period testing of metals. Chappell [8] found that, in short laboratory tests lasting three days, different varieties of iron and steel became corroded at rates appreciably different one from another; but he found that specimens of the materials exposed at the bottom of the River Severn for $2\frac{1}{2}$ years

[8] E. L. Chappell, *Ind. Eng. Chem.*, 1927, **19**, 464.

showed almost identical corrosion. No doubt after a short time on the river bottom, all the specimens became completely blanketed with rust, and the rate of attack was then determined by the rate of the very slow diffusion of dissolved oxygen through the rust-blanket, and was essentially the same for all the materials. It should be noted that specimens completely blanketed with rust will be corroded extremely slowly, owing to the restricted diffusion of oxygen; but that when part of the surface is kept free from rust, corrosion will occur quite readily, and will in general be directed on to the "unaërated" region covered with the blanket of rust.

# X-RAY STUDIES OF PARTICLE SIZE IN SILICA.

BY

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Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology.

ALTHOUGH considerable use has been made of the Scherrer method (1) of determining the particle size of colloids by the broadening of X-ray diffraction lines, comparatively little quantitative X-ray work has been done on particle sizes in the microscopic range. Czochralski (2) has demonstrated qualitatively the effect on the Laue pattern of varying the number of crystals penetrated from one large aluminum crystal to several hundred thousand minute ones in an aggregate. Glocker and Bass (3) in examining metallic crystalline aggregates such as brass and silver in sheet form have derived a linear relation between the breadth of the diffraction spots and the microscopically measured average values within the range of crystal size from 10–100 $\mu$. They also observed that the method required considerable correction when the structure was irregular.

In the course of particle size investigations in this Laboratory, through the generosity of Prof. Phillip Drinker and Mr. T. F. Hatch of the Harvard School of Public Health, the authors were provided with an excellently sized series of powdered silica specimens. It is the purpose of this paper to record the results of an X-ray examination of these specimens (the first recorded X-ray study of the effect of varying size distribution) which strikingly demonstrate the large part which size distribution plays in the X-ray pattern and the folly of attempting to estimate average particle size quantitatively from the X-ray pattern unless the size distribution is known.

The original material passed through a 325 mesh screen, and on analysis yielded 99.75 per cent. $SiO_2$. The method of

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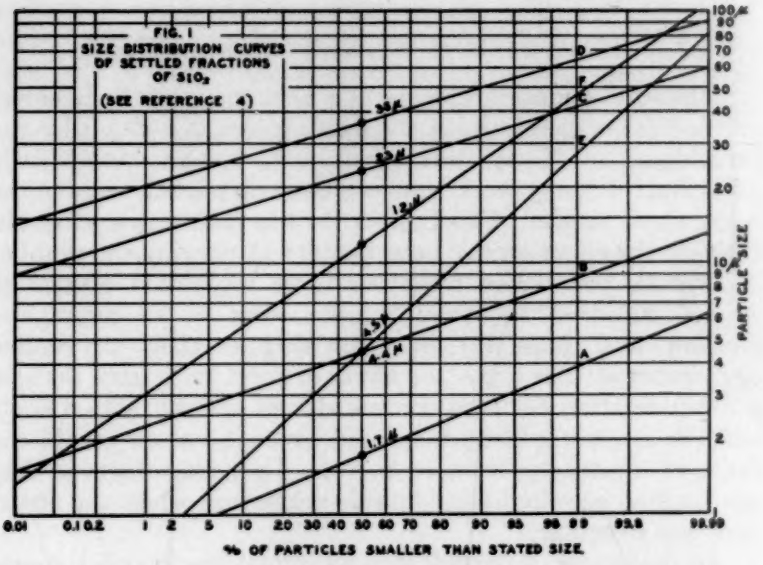
fractionating into graded sizes is described in a paper by Hatch and Choate (4). That paper also describes the derivation, significance, and application of the curves as plotted in Fig. 1 of this paper. For our purposes it will be sufficient to

FIG. 1.



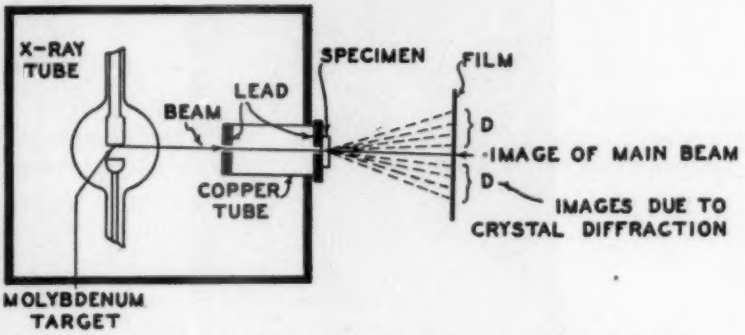

state that the particle size corresponding to the 50 per cent. point on each curve represents the geometric mean particle size, while the slope [1] is a measure of the size distribution. A horizontal curve would indicate a perfect sizing, with every particle possessing the same size as every other. The steeper the slope, the wider will be the size distribution.

The specimen containers for X-ray analysis were made of 1/16″ metal strip with 1/4″ hole, covered on both sides with thin cellophane windows. This provided specimens of constant thickness with uniform packing. The powder diffraction method was employed, using unfiltered radiation from a Coolidge molybdenum target tube operated at 30 K.V. A diagramatic sketch of this method is shown in Fig. 2.

[1] Slope is here defined as the ratio of the value at 84.13 per cent. to the value at 50 per cent. See reference (4).

The trace of the main beam on the film is masked by a lead button placed just ahead of the film. The beam was composed of both general and characteristic radiation. The latter portion consisting of a very few definite wave-lengths gives rise to diffraction effects lying on concentric rings, whose

FIG. 2.




Powder diffraction method of employing a pencil beam of X-rays and a flat film.

diameters are directly related to the spacings of atomic planes within the silica crystal particles, through the Bragg equation

$$n\lambda = 2d \sin \theta,$$

where

$n$ = the order of diffraction,

$\lambda$ = the wave length of the X-rays,

$d$ = the distance between atomic planes,

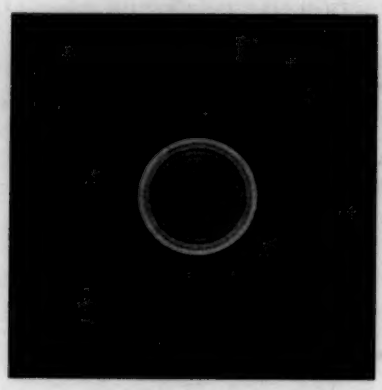
and

$\theta$ = the angle of incidence of the beam.

The portion of the beam consisting of general or "white" radiation is responsible for all other diffraction effects observed. Since, in general, each particle gives rise to a diffracted spot on the film, the total effect from a powdered specimen will be a general "peppering" of spots. The distribution will lie principally on rings due to the predominance of characteristic radiation under the above conditions. As the particles become smaller (and therefore a larger total number in the path of the beam) the individual spots become

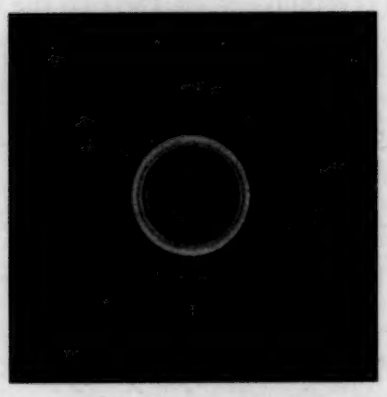
smaller and more numerous tending to overlap and merge into continuous bands or rings (Figs. 3 and 4).

FIG. 3.



Mean particle size, 1.73 μ; distribution value, 1.42.

FIG. 4.



Mean particle size, 4.4 μ; distribution value, 1.34.

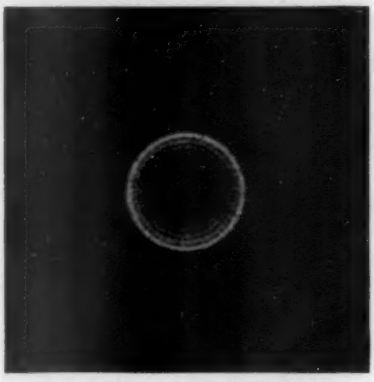
Table I gives the sizes of the six specimens expressed as mean particle size, with the size distribution expressed in units of "standard deviation" (4).

TABLE I

| Specimen. | Geometric Mean or "Average" Particle Size. | Standard Deviation. | Fig. No. of X-ray Photograph. | Fig. No. of Microphotometric Curve. |
|---|---|---|---|---|
| *A* | 1.73 μ | 1.42 | 3 | 9 |
| B | 4.4 μ | 1.34 | 4 | 10 |
| *C* | 23.0 μ | 1.30 | 5 | 11 |
| *D* | 36.0 μ | 1.28 | 6 | 12 |
| E | 4.5 μ | 2.17 | 7 | 13 |
| *F* | 12.0 μ | 1.80 | 8 | 14 |

It requires only a glance at Figs. 4 and 7 to demonstrate the tremendous effect which size distribution may have on the pattern given by two specimens with the same "average" particle size. When the size distribution is constant or

FIG. 5.



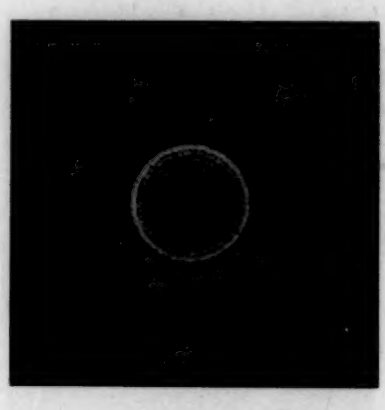
Mean particle size, 23.0 μ; distribution value, 1.30.

nearly so as with specimens *A*, *B*, *C* and *D*, tnen increasing "average" particle size is indicated by a progressive change in the diffraction pattern (Figs. 3, 4, 5, and 6).* As compared with Fig. 3, in Fig. 4 there is less fogging between the rings and the first visible traces of individual spots on the rings. In Fig. 5 the rings consist of a uniform "peppering" of distinct spots on a background less continuous than in Fig. 4. While

* In preparing prints from the negatives it was found impossible to bring out all the fine distinctions which existed in the original patterns.

the spots are fewer and larger in Fig. 6, the ring structure is still of the same type though the background has now almost disappeared.

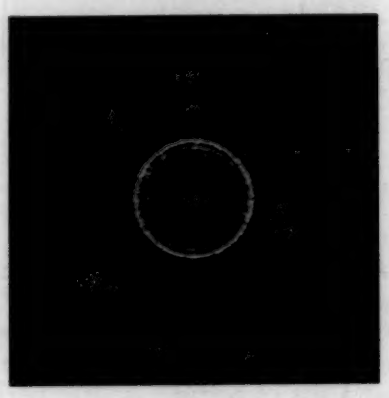
FIG. 6.



Mean particle size, 36.0 μ; distribution value, 1.28.

Figures 7 and 8 present a distinct contrast to this type of pattern. They are characterized by a heterogeneous ring

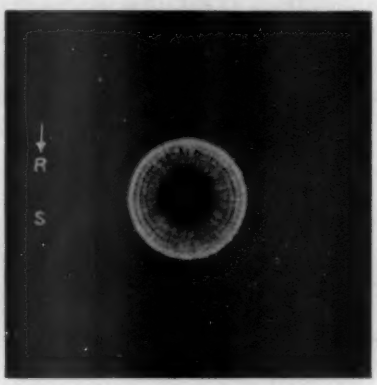
FIG. 7.



Mean particle size, 4.5 μ; distribution value, 2.17.

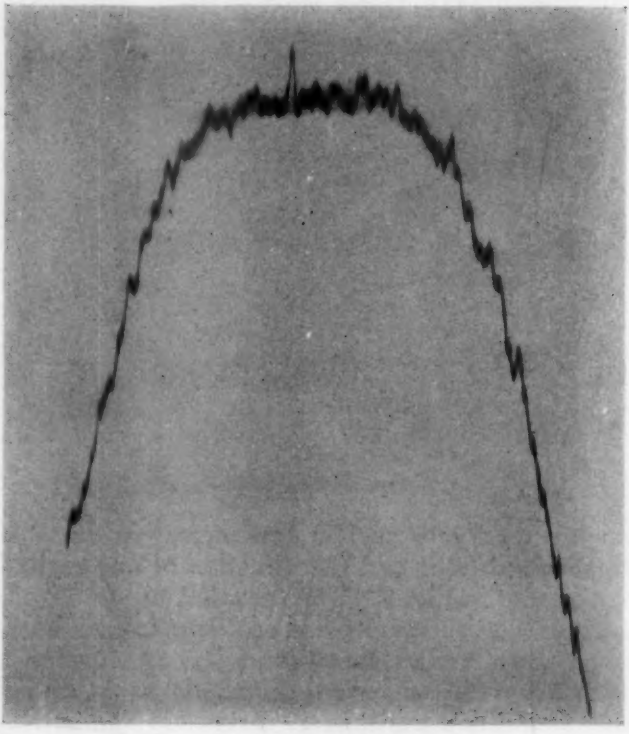
structure. This is especially clear in Fig. 7 where large spots are directly adjacent to relatively fine spots on the rings.

FIG. 8.




Mean particle size, 12.0 $\mu$; distribution value, 1.80.

FIG. 9.

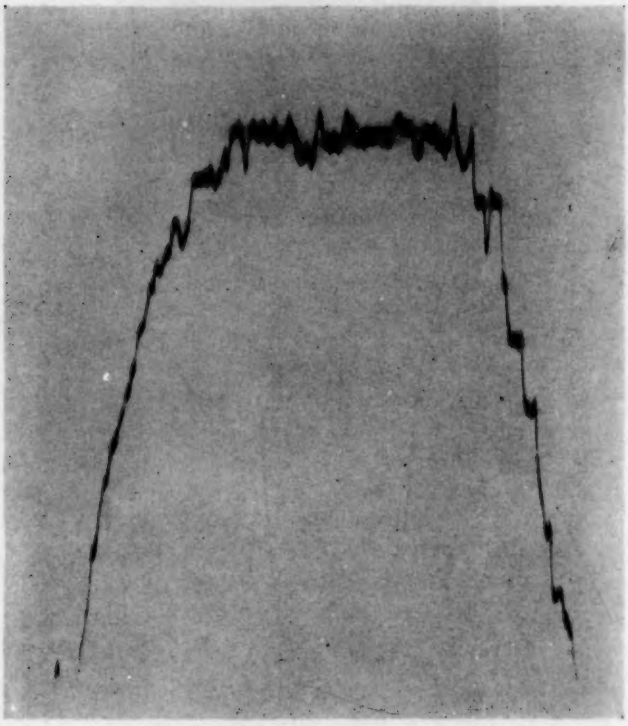


Microphotometric curve from Fig. 3

The uniform "peppering" described above is distinctly absent in these two patterns.

In order to make the results more quantitative, microphotometric studies were made on a corresponding portion of the outermost strong ring of each pattern. The micro-

FIG. 10.

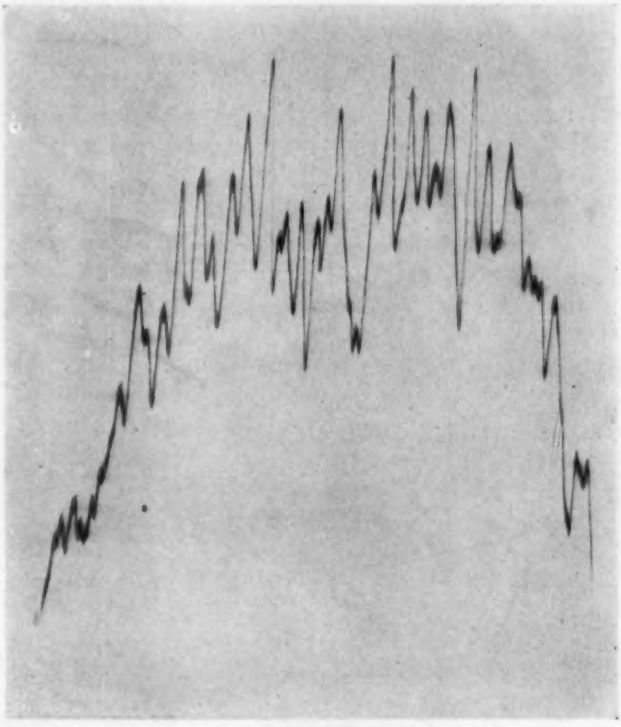


Microphotometric curve from Fig. 4.

photometer used was a Harrison densitometer (5). The region examined (*RS*) and the direction of movement of the film is indicated in Fig. 8. The recorded curves are shown in Figs. 9–14. The sharply rising portions at each end of the curves are due to the steadily increasing opacity on approaching *R* and the reverse on approaching *S*. Consequently only the central two-thirds of each curve is significant.

Within this region a number of quantities were measured. Since a "blank" run on a film exposed, developed, and photometered under the standard conditions showed no fluctuations over 0.3 cm. in amplitude, all fluctuations under 0.4 cm. were disregarded. Of all the quantities measured,

FIG. 11.

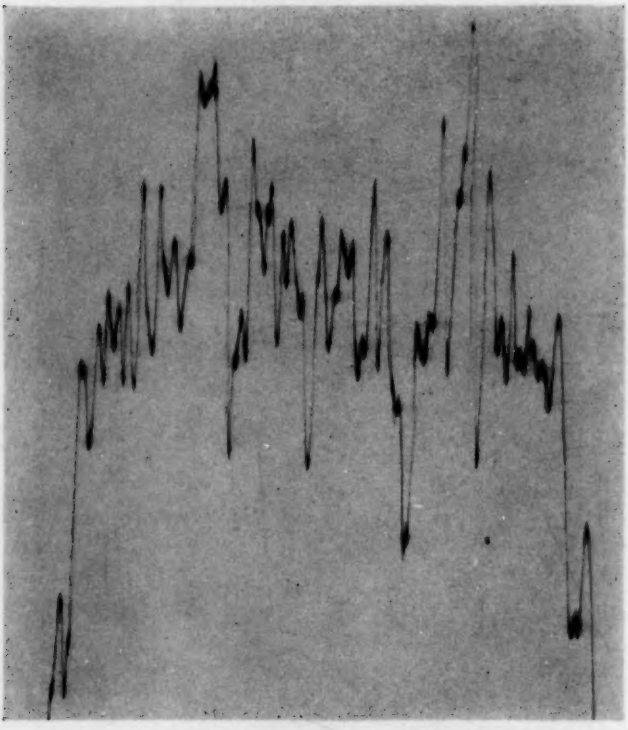


Microphotometric curve from Fig. 5.

including number of "peaks" per unit length, average height of peaks, area per peak, and total area under the peaks per unit length, the last named seemed to give the most promising results. When those values were plotted on log paper against average particle size, the points corresponding to specimens *A*, *B*, *C*, and *D* lie nearly on a straight line. The other two points (specimens *E* and *F*) do not lie on this line (although

the latter diverges slightly, the former lies at a great distance from the line). It may be noted from Table I that specimens *A*, *B*, *C*, and *D* have nearly the same size distribution. It thus seems possible that this method might be used to determine

FIG. 12.



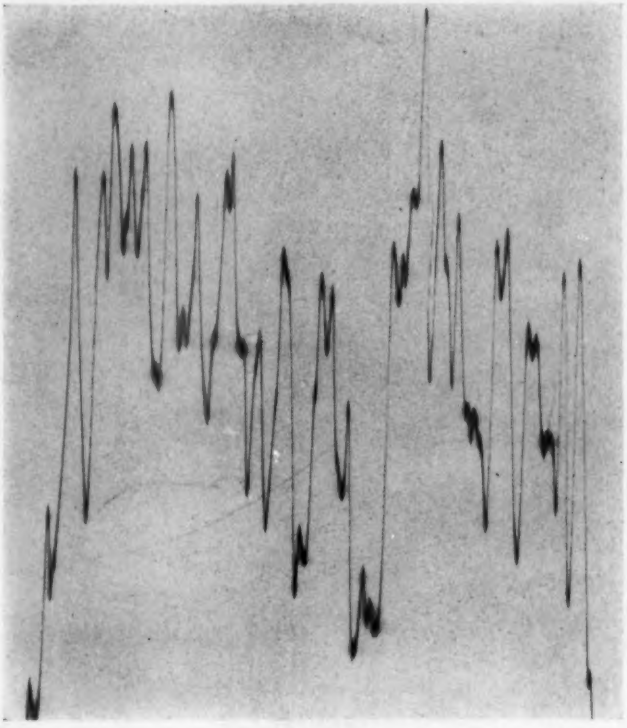
Microphotometric curve from Fig. 6.

the average particle size of specimens whose size distributions were known to be similar.

All of the above measurements as well as calculations of the coefficient of fluctuation rate of peak height (6) were studied with the hope of establishing some quantitative relationship between the pattern characteristics and the size distribution values. Nothing, however, of certain value has been obtained, possibly because the photometered region was not

sufficiently large for a satisfactory statistical average. It may be that the effect of an appreciable change in size distribution is to displace the above mentioned line, parallel to itself. In order to test this adequately a range of specimens for each of several size distribution values would be needed.

FIG. 13.

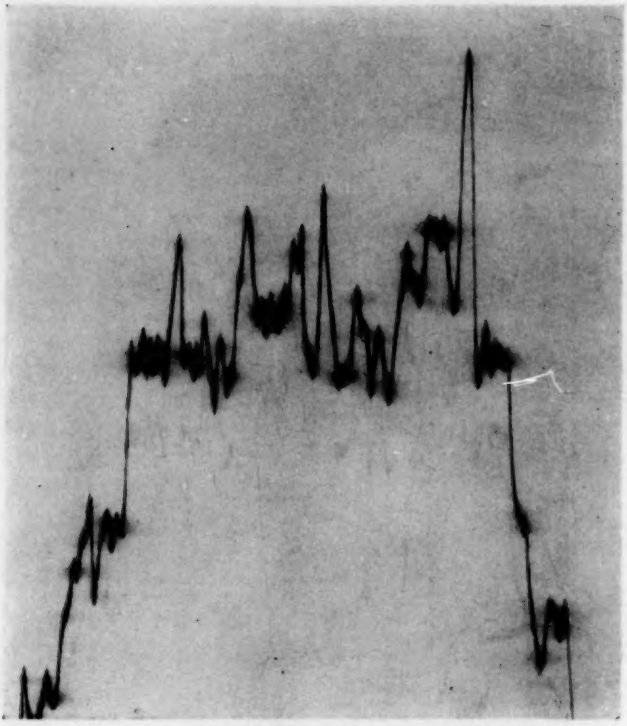


Microphotometric curve from Fig. 7.

In conclusion, it is interesting to note the similarity of these observations with the recent work of Patterson (7). He has brought out the highly important fact that the value obtained by the application of the Scherrer method (1) to the determination of the particle size of colloids is the mean value of the reciprocal of the particle size. Obviously, only when all particles have the same size can the desired value be

directly determined. In all other cases unless the size distribution is known it is impossible to determine the true average size from the broadening of the X-ray diffraction lines.

FIG. 14.



Microphotometric curve of Fig. 8.

SUMMARY.

1. The examination of a series of very carefully sized powdered silica specimens ranging in average size from 1.73 to 36.0 $\mu$ has demonstrated the important part which size distribution plays in the X-ray pattern, and the necessity of knowing this distribution before attempting to estimate the average particle size.

2. Distinct qualitative differences have been pointed out in the characteristics of X-ray diffraction patterns of specimens:

(*a*) With varying average particle size and the same size distribution.

(*b*) With varying size distribution and the same average particle size.

3. Microphotometric analysis of the patterns yielded promising results for a quantitative relationship between pattern characteristics and average particle size when the size distribution was approximately constant. No satisfactory quantitative relation was found between pattern characteristics and varying size distribution.

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**To Albert Einstein on his Fiftieth Birthday.** PROF. M. VON LAUE. (*Naturwissensch.*, March 15, 1929.) "Physics in 1929 is different from the same science in 1904 and immensely richer. The history of this science will place over this epoch not a single name, nor even two or three names alone. It is, however, assured that the name of Einstein will be one of the first to be there inscribed.

"We are embarrassed if we must say which of his ideas has most continuously influenced investigation. To-day we cannot separate from Physics the 1905 Theory of Relativity which, by rejecting the ancient prejudice for 'absolute' time, solved at a stroke the century-old riddles of the ether and of the electrodynamics and optics of moving bodies. Nor can we to-day conceive of Thermodynamics without the quantum theory of specific heat nor of atomic theory without the '$h\nu$ relation.' All these we owe to the work of Einstein as a young man.

"For these reasons physicists salute Albert Einstein as a pioneer of the first order. And shall physicists alone do this? Shall not also chemists for whom the conception of the absorption of radiation by quanta has furnished a new basis for photochemistry? And astronomers for whom he explained the puzzling motion of the perihelium of Mercury and whom he incited to discover the deviation of light by the sun and led to investigate with care the shifting of spectral lines? And not also mathematicians to whom he showed how Nature makes real non-euclidean geometry and to whom he has pointed out recently a road to a new generalization of this geometry? And perhaps even professional philosophers will join in the acclaim for, no matter what value they may attach to the Theory of Relativity, they must recognize the service of one who in an age far removed from idealism has directed the attention of wide circles to the importance of the philosophical criticism of knowledge."

G. F. S.

# LIGHT-TRAPS IN THE CONTROL OF INSECTS.

BY

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INSECTS may be classified as harmful, neutral or beneficial according to their effect upon vegetation. There are many kinds of harmful insects of which the Hessian-fly, boll weevil, codling moth, chinch-bug, grasshoppers, the gypsy and brown-tail moths are conspicuous examples.

Some insects are not only beneficial, but necessary in the economics of nature. Indeed, the group of beneficial insects, made up chiefly of predacious and parasitic insects, constitutes the most effective means whereby harmful insects are held in check.

The methods for the control of insects may be sub-divided into three general classes:

(*A*) Mechanical,
(*B*) Chemical,
(*C*) Biological.

A few of the mechanical methods used by farmers for the control of insects are:

(1) Trap crops,
(2) Cleaning up rubbish and weeds,
(3) Early planting,
(4) Rotation of crops,
(5) Using resistant varieties,
(6) Fertilization and culture,
(7) Burning,
(8) Collecting eggs,
(9) Manual destruction of insects,
(10) Late fall plowing,
(11) Light-traps.

Insecticides constitute the main group of chemical agents used in the control of insects. The life history and habits of a pest and the kind of mouthparts it has—whether biting or sucking—influence the choice of insecticide to use against it. The three general classes of insecticides are:

(*a*) Poisons for biting insects,
(*b*) Contact substances for sucking insects,
(*c*) Gases for biting and sucking insects.

The most common biological agents employed in the warfare against injurious insects are birds, parasitic and predacious insects, and fungus diseases. These biological agents are seldom purposely employed, but they are nevertheless always more or less in action. Indeed, if insects were not continually fighting each other they would gradually destroy the human race.

It has been estimated by entomologists[1,2,3,4] that on an average there are destroyed by insects in the United States in a year about 20 per cent. of truck crops, 15 per cent. of fruits, 10 per cent. of staples, 5 per cent. of animal products, and 1½ per cent. of stored food products. This gives a total loss due to insect pests of more than two billion dollars a year.

It has also been estimated that malarial diseases borne by the Anopheles mosquitoes cause an annual loss to the people of the United States of not less than $100,000,000.

These enormous losses take place, notwithstanding the numerous methods employed in an effort to control the insects. Where it is not combated the codling moth, or apple worm, causes a loss of from 30 to 50 per cent. of orchard crops. It is thus apparent that the use of a huge additional annual expenditure in fighting insects would be entirely justifiable if only a small proportion of the present annual destruction by insects could be prevented.

In the control of insects by the use of traps baited with light, advantage is taken of the fact that most insects are either positively or negatively phototropic; that is, they are either attracted or repelled by light.

The reactions of insects and other organisms are in general adaptive,[5] and cause the organisms to collect under light

conditions which facilitate life processes; and it is usually under artificial conditions only that the positive reactions of insects result fatally. Due to changes of internal states of organisms, they may be positive to light of a given intensity at one time and negative to the same intensity at another. However, a reversal in the sense of reaction is not common to all organisms which respond to light. Frequent causes of change of activity are prolonged exposure to light, nutrition, age, time of egg-laying, etc.

Davenport [6] found that light having an intensity above that to which an organism is attuned repels the organism. Or as Jennings [7, 8] puts it—many organisms are positive to weak light; negative to strong. Davenport also found that young larvæ of certain kinds upon first leaving the shell of the parent are positively phototropic, but after being in the light from 1/4 to 2 hours they become negatively phototropic. He notes that the response of an organism to light, as exhibited in movements, is in harmony with the metabolic state of the organism; and he concludes generally that the response of the organism is the result of chemical changes in the protoplasm wrought by the light. The behavior of an organism at any moment depends upon its physiological state at the moment.

Upon observing certain museum and carpet pests Wodsedalek [9] found them to be negatively phototropic until their eggs had been deposited, after which their reactions to light soon reversed. Weiss [10] discovered that near the close of the season impregnated females of certain species of mosquitoes became strongly negatively phototropic and sought dark hibernating quarters. He also discovered that up to a certain low intensity of light some species are positively phototropic and at higher intensities negatively so. He also found that different species of mosquitoes were quite unlike in their behavior toward light, some being equally positively and negatively phototropic, some unequally positively and negatively phototropic and others constantly one thing or the other.

Holmes [11] found the larvæ of certain species of mosquitoes to be very sensitive to shadows. However, larvæ frequently exposed to shadows gradually fail to respond to them. But

like most moths and many other forms which seek the shade, they frequently show a decided positive phototaxis. After a full meal, although more sluggish, they are still positive. The males show the same positive reactions as the females.

Since a trap set with a lantern as a lure caught a much larger variety of insects when moving than when stationary, Holloway [12] concludes that a moving light has a greater attraction for insects than one that is fixed. Mast states that all organisms that respond to light at all respond to changes of intensity. A sudden increase and a sudden decrease of light intensity may under certain conditions produce the same reaction.

We know, according to Holmes and McGraw,[13] that changes in the intensity of light, whether an increase or a decrease, may act as a stimulus, especially if the changes are sudden. In many animals it is not so much the intensity of the light that produces a response as the shock of transition from one intensity to another. Responses to shock of transition play a part in the orientation of many forms, but the continuous stimulating influence appears in several cases at least to be the factor of major importance.

Mast states that in the lower animals with image-forming eyes the reactions to color are very much more complicated than in those without them. He states that from the results of Lubbach's experiments it appears that ants have the power of distinguishing colors and that they perceive violet and ultraviolet rays. Lubbach also concluded from his experiments on honey bees that they have the power to distinguish color and that they prefer blue. Numerous investigators working with ants, bees, wasps and other insects agree that many of these insects have color vision, although their evidence is far from conclusive. Honey bees, some fishes, birds, mammals, probably some spiders and many lower forms with well-developed eyes can probably distinguish different regions of the spectrum. With a given amount of monochromatic radiation some of these organisms are more strongly stimulated by blue, others by violet or ultraviolet, others by green and yellow and still others by red and infrared. However, with a great many organisms there is evidence that no one color is much more effective than another.

Although it is theoretically possible that colored light may have the advantage in some cases of attracting certain deleterious insects without attracting beneficial ones this has not yet been proved in actual cases.

After reviewing the literature on the subject, Montgomery [14] concludes that there is no evidence that spiders possess the sense of hearing but the sense of smell is possessed by all spiders.

From his observations upon giant silk-worm moths, Turner [15] concludes that most specimens respond to high notes (sounds probably resembling those having a life significance), but that they do not respond to low pitch sounds (unless by remaining as immovable as possible be considered a response) until they have learned by rough treatment to associate some disagreeable experience with these sounds.

In a series of papers McIndoo [16, 17, 18] gives an extensive bibliography on the olfactory sensations of insects. He also gives a long list of odoriferous substances and states that honey bees, hornets, ants and spiders usually respond to the odors of those substances by moving away from them, thus proving that all these forms can smell.

Richardson [19] found that the house-fly is attracted by both ammonium hydrate and ammonium carbonate. Since practically all animal excrement gives off ammonia, he concludes that it is probably the ammonia gas which attracts flies to manure.

By attaching shallow pans, containing kerosene, to the branches of fruit trees, Severin and Severin [20] were able to catch large numbers of Mediterranean fruit flies. They concluded that the sense of smell probably was the determining factor in attracting these insects to the kerosene. However, out of 5,491 flies caught 5,461 were males and only 30 were females. Since the reaction was practically confined to the male sex and appeared to be connected in no way with feeding habits, it seemed most reasonable to suppose that the smell might resemble some sexual odor of the female which under natural conditions served to guide the male to her.

We made some preliminary tests with light-traps during the summer of 1928. The light-trap illustrated is one of

several used by us and is more or less representative of those used by other investigators. It consists of a 200-watt clear bulb Mazda lamp suspended several inches above a shallow pan about three inches deep and 24 inches square filled with water having a film of kerosene about 1/16 inch thick over its surface.

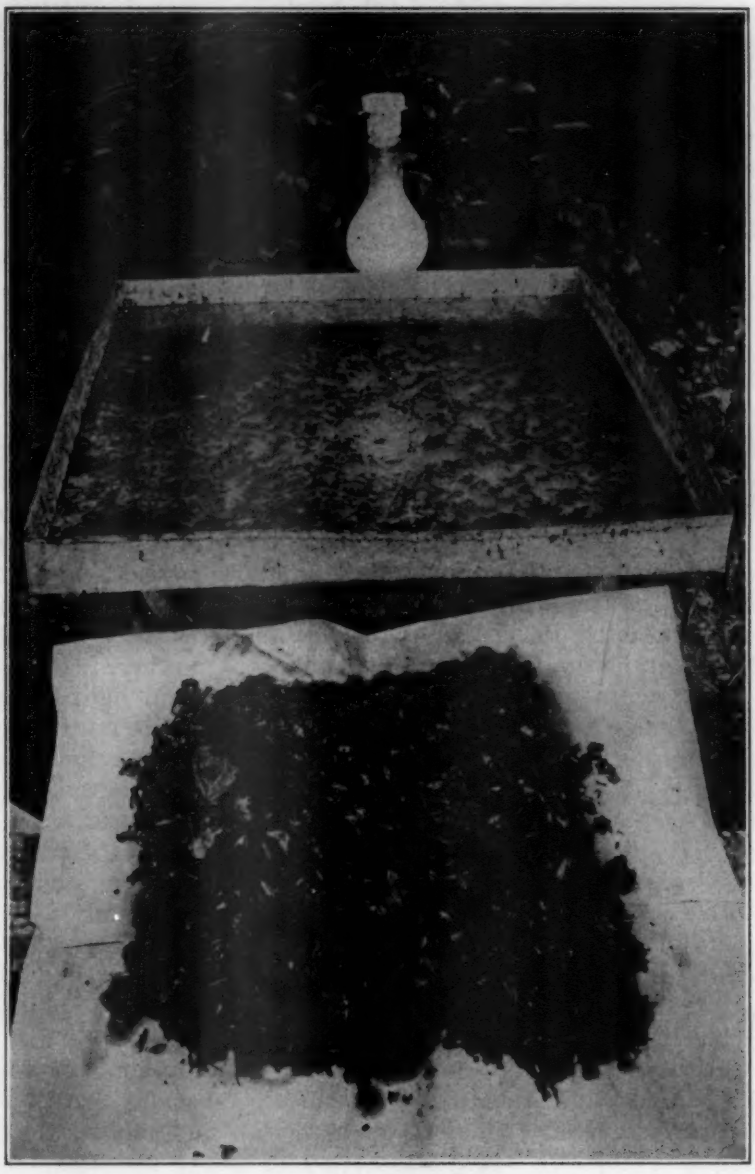
The traps were set in a small clump of bushes and about 200 feet from a wooded ravine. Owing to the presence of street and residence lights nearby and no crops around, the conditions surrounding the traps were far from typical. In Table I are presented the relative weights of insects of all kinds caught in the various traps, mounted at heights varying from zero to six feet from the ground and baited with clear-bulb Mazda lamps varying in size from 75 to 300 watts.

TABLE I.

*Relative Weights of Insects of all Kinds Caught in Light-traps, each Consisting of an Incandescent Tungsten Lamp Suspended about Six Inches above a Shallow Galvanized Iron Pan Containing Water over which There Was a Thin Layer of Kerosene.*

| | |
|---|---|
| 24-inch pan, 100-watt lamp, three feet above ground | 80 Appr. |
| 24-inch pan, 200-watt lamp, three feet above ground | 100 |
| 24-inch pan, 300-watt lamp, three feet above ground | 120 |
| 24-inch pan, 200-watt lamp, six feet above ground | 80 |
| 15-inch pan, 200-watt lamp, with pan on ground | 70 |
| 15-inch pan, 200-watt lamp, three feet above ground | 80 |
| 15-inch pan, 75-watt lamp, three feet above ground | 70 |
| 24-inch pan, 200-watt lamp, three feet above ground, surrounded with wire gauze cage | 70 |

As may be seen from the table, it appears better to have the trap about three feet from the ground than to have it either on the ground or six feet above the ground. The higher the wattage input of the lamp the better. Although the catch was not in proportion to the watts, the catch increases with the wattage or luminous intensity of the light-source. Also the 24-inch pan caught more insects than the 15-inch one. It was observed that many more insects were caught per night in the early part of the season than in the late summer or fall. Weather conditions were observed to greatly influence the number of insects caught. Cloudy nights, absence of moonlight, absence of strong wind, slight



A close-up of a light-trap showing the number and variety of insects caught per night in early summer.

fog or the presence of fine warm rain are conditions which seemed to increase the size of the catch.

No attempt was made to separate the insects caught according to species or sex, and there being no growing crops around the traps, the benefit accomplished could not be estimated. From an inspection of Fig. 1 some idea may be formed of the number and variety of insects caught per night in early summer.

The ideal procedure in the control of insects would be to catch and destroy at a reasonable cost all harmful and possibly all neutral insects before they lay their eggs or injure vegetation; and to leave undisturbed all beneficial insects. However, to be able to do this successfully by the use of light-traps, a thorough knowledge should be had of the life history, mating, egg-laying, phototropic, and other habits of the insect pest and his natural enemies. Here, as in fishing, the bait should be suited to the catch. Any insect that is not an enemy of the particular pest or pests to be controlled should probably be considered neutral or undesirable and therefore suitable for trapping. Thus it seems probable that a given insect may be beneficial under one circumstance, neutral under another and even harmful under still another.

The types of insects that may be caught in light-traps are of course those that are active at night and are positively phototropic. Although no extensive study has been made of the types of harmful insects that may be caught by light-traps, yet success has been had in trapping June-beetles, tortrices, moths, flies, beetles, the codling moth in captivity,[22] army cutworm,[23] tomato moths,[24, 25] pickle beetle, cotton moth,[26] gnats,[27] mosquitoes,[28] etc. On the other hand, many destructive kinds of insects such as the corn ear-borer and codling moth apparently are not much attracted by lights.[1] Also light-traps have not proved of great value in controlling orchard insects or cereal pests.[23]

Although there are indications that some insects are not color blind,[29] and that many insects are especially sensitive to the ultraviolet radiations of acetylene and mercury arc lamps, yet "white" light has been found very attractive to most varieties of insects.[30]

By analyses of the catches of insects during a season

it has been found that with certain kinds of insects at certain times of year the proportions of males and females are about equal and in other instances, notably during the winter months, there is a preponderance of males.[21]

From a study of the results of investigations made by others it appears that the use of light-traps in the control of insects that prey upon garden vegetables might prove very effective. In Virginia with from one to three light-traps per acre [24] and in Alabama with four light-traps per acre [25, 31] savings of from 30 to 50 per cent. were effected on tomato crops. If similar savings could be effected by the use of light-traps with other truck crops it is conceivable that by the use of light-traps hundreds of millions of dollars might be saved on truck crops alone each year.

A fly-trap baited with a 100-watt lamp and constructed to kill the insects by contact with high voltage wires was set in a dairy barn and, during a period of sixty days, caught about 100,000 flies and many moths, beetles and other insects.[28]

By the use of a wire screen trap baited with a 300-watt lamp, Burgett [27] was enabled to catch per season on Clear Lake in California 126 pounds of gnats or about 300,000,000 insects.

In greenhouses [23] and cold storage warehouses [22] light-traps have been very effective in clearing these places of insects and preventing large future generations of them.

There appear to have been no experiments made in baiting traps with flashing lamps or intermittent light-sources. Nor do attractive odors or sounds in conjunction with lights appear to have been used to lure insects into traps. It may be emphasized here that the light-sources, odor and sound would have to be especially selected to trap the type of pest to be controlled. With a suitable combination of light, odor and sound it might be possible to attract a pest and repel his enemies from a trap.

In conclusion it may be remarked that too few serious investigations have been made to determine the practicability of using light-traps to control insects; and in most of the investigations that have been made, the many variables apparently have not been seriously considered even though

in some cases sweeping conclusions have been drawn. However, it appears that there are opportunities for using light-traps to control insect pests with an economic gain enormously exceeding the cost of operating such devices. Although thorough investigations are needed in this field, individuals engaged in the growing of food-supplies can make valuable contributions by careful tests in their own specific cases. Traps can be easily made and the operating cost is slight.

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The foregoing is by no means a bibliography of the subject, but should be helpful to anyone newly interested in the subject.

**The Application of the Properties of Thin Metal Films to the Manufacture of Delicate Electric Fuses.** (*Jour. Scientific Instruments*, March, 1929.) In the last years patents relating to the use of thin metal films for fuses have been taken out in Great Britain, France, Germany and the United States, and fuses are on the market that blow at currents ranging from 5 milliamperes upward. Performance tests are cited that show such fuses to blow close to their rated capacity. Their resistances are high. A 25 milliampere fuse has a resistance of 58.4 ohms. An 80 milliameter fuse has a time of operation of less than one-thousandth sec.

The action of the metal film as a fuse is connected with a phenomenon noticed by Faraday in 1857. "When gold or silver leaf was laid on glass and warmed, the leaf became transparent at a temperature far below the melting point of the metal. It is important for the present purpose to notice that the loss of color is accompanied by a loss of thermal and electrical conductivity.

"When a current just above the carrying capacity of the fuse is passed the middle of the strip will attain the highest temperature. This temperature has only to reach 200° to 400° C.—depending on the thickness of the film—for disconnection to occur. A fuse which has operated has what looks like a fine scratch across its center in a direction at right angles to its length."

In addition to rolling and beating there are several ways of making the thin metal films. Some of the very thin ones are made from a gold-silver alloy rich in gold. "They are so thin that it is possible to read newspaper print through several thicknesses of them. They are perfectly continuous and vary between green and blue in color for transmitted light. To reflected light they are pale yellow when of gold leaf thickness, but when excessively thin the films have a slightly red color. They are prepared by electrodeposition. The basis of this method was invented by Outerbridge of Philadelphia in 1877."

G. F. S.

## MEDAL DAY MEETING.

THE annual Medal Day meeting of The Franklin Institute was held in the Hall of the Institute at three-thirty on the afternoon of Wednesday, May fifteenth, 1929. It was also the stated monthly meeting of the Institute, and was called to order by Mr. Nathan Hayward, President.

After the approval of the minutes and the announcement of other items of business pertaining to the affairs of the Institute, which have been printed in full in the June number of the JOURNAL, the principal business of the day, the presentation of medals which had been awarded upon recommendation of the Committee on Science and the Arts, was carried out.

### CERTIFICATE OF MERIT.

To Mr. G. F. Machlet, Elizabeth, N. J. Professor W. Chattin Wetherill, sponsor.

The Chair recognized Mr. Wetherill.

Mr. Wetherill: "Mr. President, I have the honor to present to you, in absentia, upon recommendation of the Committee on Science and the Arts, Mr. George F. Machlet of the American Gas Furnace Company, Elizabeth, New Jersey, as the recipient of a Certificate of Merit, in consideration of his pioneer work in perfecting the automatic temperature control for gas-fired furnaces."

Mr. Hayward presented the certificate and report to Mr. Machlet's brother, in the following terms: "Mr. Machlet, by virtue of the authority conferred upon me as its President by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon recommendation of the Committee on Science and the Arts, and with the unanimous approval of the Board of Managers of the Institute a Certificate of Merit, and beg that you transmit it to your brother."

Mr. Machlet expressed his thanks on behalf of his brother.

AWARD OF LONGSTRETH MEDALS.

To Mr. Edward G. Herbert, Manchester, England. Mr. E. W. Smith, sponsor.

The Chair recognized Mr. Smith.

Mr. Smith: "Mr. President, upon recommendation of the Committee on Science and the Arts, I have the honor to present to you, in absentia, Mr. Edward G. Herbert of the Atlas Works, Manchester, England, as the recipient of a Longstreth Medal, in consideration of his technical ability in the development of the Pendulum Hardness Tester and the contribution he has made to the general knowledge of the subject of the hardness of metals. Mr. Frederic Watson, British Consul General in Philadelphia, will receive the medal on behalf of Mr. Herbert."

The President presented the Medal and Certificate as follows: "Mr. Consul General, I have much pleasure in presenting to you, in the name of The Franklin Institute of the State of Pennsylvania, upon recommendation of its Committee on Science and the Arts, and with the full approval of its Board of Managers, the Longstreth Medal and Certificate, which I would ask you to forward to Mr. Herbert in England."

The Consul expressed his thanks on behalf of Mr. Herbert.

To Dr. Konrad Jagschitz, Mainz, Germany. Mr. J. M. Rusby, sponsor.

Mr. Hayward called upon Mr. Rusby.

Mr. Rusby: "Mr. Chairman, upon recommendation of the Committee on Science and the Arts, I have the honor to present to you, in absentia, Dr. Konrad Jagschitz of Mainz, Germany, as the recipient of a Longstreth Medal, in consideration of the technical merits of his invention, the Waterless Gas Holder, which have been proved by practical use. Dr. Drechsler, of the German Consulate General's office of New York City, will receive the medal on behalf of Dr. Jagschitz."

The Chairman presented the Medal and Certificate and said: "Mr. Consul, I am very glad to present to you, in behalf of your countryman, and with the full approval of the Board of Managers of The Franklin Institute, acting upon the recommendation of its Committee on Science and the Arts, the

Longstreth Medal and Certificate, for Dr. Konrad Jagschitz. May we impose further on your kindness by asking you to send these to Dr. Jagschitz? I wish to express to you at this time our deep appreciation of your goodness in taking the trouble of coming from New York to participate in these exercises. We are grateful to you."

Dr. Drechsler, the Consul, thanked the President.

The following cablegram from Dr. Jagschitz was read: "I deeply regret being prevented from taking part in Medal Day. My best compliments for the celebration."

To Mr. Adolph W. Machlet, Elizabeth, N. J. Mr. F. V. Hetzel, sponsor.

The Chair recognized Mr. Hetzel.

Mr. Hetzel: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. Adolph W. Machlet of the American Gas Furnace Company, Elizabeth, New Jersey, as the recipient of a Longstreth Medal, in consideration of his improved method of case hardening and the construction of gas carburizing apparatus for that purpose, whereby the cost of case hardening is reduced, a greater uniformity of hardened surface secured, and the equality of the work kept under control and thereby improved.

The Chairman presented the Medal and Certificate and remarked: "Mr. Machlet, by authority vested in me, I am happy to confer upon you, by action of our Board of Managers, acting upon recommendation of its Committee on Science and the Arts, a Longstreth Medal and Certificate. I wish to congratulate you upon this deserved recognition."

Mr. Machlet accepted the award with thanks.

To Mr. J. F. Peters, East Pittsburgh, Pa. Mr. C. E. Bonine, sponsor.

The Chair recognized Mr. Bonine.

Mr. Bonine: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. J. F. Peters of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, as the recipient of a Longstreth Medal, in consideration of his

successful development of the Klydonograph, a practical instrument for the recording of voltage surges on transmission lines."

The President presented the Medal and Certificate, with the statement: "Mr. Peters, I have much pleasure in presenting to you, upon recommendation of our Committee on Science and the Arts, this Longstreth Medal and Certificate and wish to express my satisfaction that the Committee has brought your work to our attention."

Mr. Peters expressed his thanks and sincere appreciation of the honor.

## AWARD OF WETHERILL MEDALS.

To Mr. Gustave Fast. Mr. C. D. Galloway, sponsor.

Mr. Hayward called upon Mr. Galloway.

Mr. Galloway: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. Gustave Fast of the Bartlett Hayward Company, Baltimore, Maryland, as the recipient of a Wetherill Medal, in consideration of the novelty of design of his Self-Aligning Coupling, the stability of its construction, and of its successful practical application."

The President then presented the Medal and Certificate in the following manner: "Mr. Fast, by virtue of the authority conferred upon me as its President by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon recommendation of the Committee on Science and the Arts, and with the unanimous approval of the Board of Managers of the Institute, a John Price Wetherill Medal and Certificate. I assure you we are most happy to have you added to our honor list."

In acknowledging the award, Mr. Fast said: "It is indeed a very great honor upon which I shall always look with gratitude."

To Mr. W. H. Mason, Laurel, Mississippi. Mr. M. M. Price, sponsor.

The Chair recognized Mr. Price.

Mr. Price: "Mr. President, upon recommendation of the Committee on Science and the Arts, I have the honor to

present to you, Mr. William H. Mason of Masonite Corporation, Laurel, Mississippi, as the recipient of a Wetherill Medal, in consideration of the development of his process for the successful use of wood waste, known as Masonite and Presdwood."

Mr. Hayward, in presenting the Medal and Certificate, said: "Mr. Mason, I am very glad to present to you, on behalf of The Franklin Institute and upon the recommendation of its Committee on Science and the Arts, and with the hearty approval of its Board of Managers, a Wetherill Medal and Certificate. We are gratified to have you enrolled with us and thank you sincerely for your interest in taking the long trip which you did to receive this Medal personally."

Mr. Mason said: "I can't tell you how much I appreciate it."

To Dr. Johannes Ruths. Mr. Bonine, sponsor.

The President called upon Mr. Bonine.

Mr. Bonine: "Mr. President, upon recommendation of the Committee on Science and the Arts, I have the honor to present to you, in absentia, Dr. Johannes Ruths of Djursholm, Sweden, as the recipient of a Wetherill Medal, in consideration of the excellence of design of the control equipment and the adaptation of sound principles to the successful production of large steam storage apparatus. Mr. Hogeland, Royal Vice Consul of Sweden, will receive the medal on behalf of Dr. Ruths."

In presenting the Medal and Certificate, Mr. Hayward said: "Mr. Consul, it gives me much pleasure to give to you for transmission to Dr. Ruths, a native of the country which you are representing in Philadelphia, this Wetherill Medal and Certificate. We appreciate your kindness in performing this service for us."

Mr. Hogeland said: "Mr. President please permit me to express, on behalf of Dr. Ruths, his warmest gratitude for the honor which has been conferred upon him by the Institute."

The following cablegram, which had been received from Dr. Ruths, was read by the Secretary: "Just returned from trip to Africa and received your kind letter January twenty-fourth. Feel highly pleased with honor extended by Franklin

Institute. Very much regret my absence on presentation day. Request you to convey sincerest thanks to Committee. Have asked Swedish Vice-Consul to receive Medal for me May fifteenth. Cordial greetings."

### AWARD OF LEVY MEDAL.

To Mr. L. J. R. Holst. Dr. T. D. Cope, sponsor.

The Chair called upon Dr. Cope.

Dr. Cope: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. Lodewyk J. R. Holst, of Brock and Weymouth, Inc., Philadelphia, as the recipient of the Levy Medal, for his paper, 'Topography from the Air' which was published in the October, 1928, issue of the JOURNAL OF THE FRANKLIN INSTITUTE."

In handing the Medal and Certificate to Mr. Holst Mr. Hayward said: "Mr. Holst, I am most happy to confer upon you the Louis Edward Levy Medal and Certificate, with congratulations to you upon the high quality of the article upon which this award is based. You richly deserve this honor."

Mr. Holst, said: "I want to express my deep thanks and great appreciation of the honor bestowed upon me."

### AWARD OF CLARK MEDAL.

To Mr. W. H. Gartley. Mr. J. S. Rogers, sponsor.

The Chair recognized Mr. Rogers.

Mr. Rogers: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. William H. Gartley of the Philadelphia Gas Works Company, Philadelphia, as the recipient of the Clark Medal, in consideration of his engineering contributions to the advancement of the gas industry, to the development and practical operation of large city gas works, and of his ingenuity, sound judgment, and service to the public in his field of work."

In presenting the Medal and Certificate, Mr. Hayward stated: "Mr. Gartley, it is with especial gratification that I present to you this Walton Clark Gold Medal and Certificate. The Committee's report signifies that your labors have been

such as to make you altogether worthy of this award. I would like to add a word of satisfaction at this award. I know that if Dr. Walton Clark were here he would say that this medal was going to his 'right hand.' "

In receiving the Medal, Mr. Gartley said: "Mr. President, I want to express my appreciation of this honor which has been conferred upon me by this world-famous Franklin Institute."

## AWARD OF CRESSON MEDALS.

To Sir James C. Irvine. Dr. H. J. Creighton, sponsor.

The Chair called upon Dr. Creighton.

Dr. Creighton: "Mr. President, upon recommendation of its Committee on Science and the Arts, I have the honor to present to you, in absentia, Sir James C. Irvine, Principal of the University of St. Andrews, Scotland, as the recipient of the Elliott Cresson Gold Medal, in consideration of his brilliant researches in the field of carbohydrate chemistry. Mr. Frederic Watson, British Consul General in Philadelphia, will receive the Medal on behalf of Sir James."

In giving the Medal and Certificate to Mr. Watson, Mr. Hayward said: "Mr. Watson, again I have the pleasure of presenting to you, for transmission to the distinguished scientist whom you are representing here today, Sir James C. Irvine, a Cresson Gold Medal and Certificate. I wish to say to you that The Franklin Institute is exceedingly grateful for your kindness in participating in these exercises today. We thank you most sincerely."

When he received the Cresson Medal, Mr. Watson, the British Consul, said: "Mr. President, it is always a great pleasure and honor for me to come here to receive the medals bestowed by The Franklin Institute on countrymen of mine, more learned and more enterprising than myself. It is a behest which I shall always try to follow with alacrity; and I shall feel in subsequent years, if I am not called upon at this time of the year, that learning and science are on the downward grade in Great Britain."

The secretary then read the following letter from Sir James C. Irvine:

THE UNIVERSITY
ST. ANDREWS

From
Sir James Colquhoun Irvine,
Principal and Vice-Chancellor. 14th March, 1929.

*My dear Mr. McClenahan,*

Your letter of February 28th has given me the utmost pleasure and I find it difficult to express in words my thanks to the Board of Managers of the Franklin Institute for the award of the Elliott Cresson Gold Medal. This recognition of my work carries to me a special significance as it adds yet another tie to the many which bind me to the scientists of the United States. The connection between St. Andrews and Philadelphia is of long standing, for Benjamin Franklin received his first Honorary Degree from this University and James Wilson, who subscribed to the Declaration of Independence, was a student of my own College. These recollections add to the gratification I now feel.

My pleasure in receiving your news is, however, marred by the fact that I cannot attend in person to receive the award. In my busy life dates are necessarily arranged for some months in advance, and I see no prospect of uncoiling the commitments to which I am already pledged for the summer. May I ask you therefore to express to the Board of Managers my heartfelt gratitude for the distinction they have so kindly conferred on me and also my regret that I cannot join in the exercises on Medal Day.

Believe me, with all kind regards,

Yours sincerely,
J. C. IRVINE.

The Secretary,
The Franklin Institute,
Philadelphia.

To Dr. Chevalier Jackson. Dr. J. S. Hepburn, sponsor.

Mr. Hayward called upon Dr. Hepburn.

Dr. Hepburn: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Dr. Chevalier Jackson of the Jefferson Medical College, Philadelphia, as the recipient of the Elliott Cresson Gold Medal, in consideration of his researches on the mechanical principles involved in the removal of foreign bodies from respiratory and food passages; of his designing of many instruments for this purpose; and of his development of a technique for the use of these instruments."

Mr. Hayward made the award as follows: "Dr. Jackson, by virtue of the authority conferred upon me as its President by The Franklin Institute of the State of Pennsylvania, I have profound pleasure in presenting to you, upon the recommendation of the Committee on Science and the Arts and with the

unanimous approval of the Board of Managers of the Institute, this Elliott Cresson Gold Medal and Certificate. The Franklin Institute has always tried to serve the interests of mankind and to honor those who do likewise. It therefore gives us a peculiar satisfaction to honor you for your distinguished contributions to surgical science through the agency of physical instruments, which have been a great boon to suffering humanity."

Dr. Jackson responded: "Mr. President, I do not know words adequate to express my appreciation. I can only say, I thank you."

To Dr. Elmer A. Sperry. Dr. Frederic Palmer, Jr., sponsor.

The President called upon Dr. Palmer.

Dr. Palmer: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Dr. Elmer A. Sperry, President of the Sperry Development Company, Inc., Brooklyn, New York, as the recipient of the Elliott Cresson Gold Medal, in consideration of his application of the principle of the gyroscope to the development of means whereby vessels may be navigated with greater safety, comfort, and economy, both in time and fuel, and whereby the irregularity of movement of vessels and trains may be accurately recorded."

In presenting the Medal and Certificate, Mr. Hayward remarked: "Dr. Sperry, in the name of The Franklin Institute, I am delighted to present to you the Elliott Cresson Gold Medal and Certificate for your remarkable adaptation of this scientific principle to the comfort and well being of mankind. We are honored in having you numbered among our Medalists."

Upon receiving the award, Dr. Sperry said: "I feel with the Doctor that words are wholly inadequate. It is certainly the highest possible honor that can come to a worker, to be recognized by this Nestor of all scientific and technical bodies in our great country—The Franklin Institute. I certainly thank you."

## AWARD OF FRANKLIN MEDALS.

To Mr. Emile Berliner, Washington, D. C. Dr. James Barnes, sponsor.

The President called upon Dr. Barnes.

Dr. Barnes: "Mr. President: The Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts is unanimously of the opinion that a Franklin Medal be awarded to Emile Berliner, of Washington.

> "'In recognition of a life-work in successful invention: the discovery of the electrical characteristics of the loose contact and application of them to telephony in the microphone, which he originated; development of the talking machine which uses a disc upon which the sound is recorded by a laterally cut groove; and, in recent years, his contributions to the production of proper acoustical qualities in architectural structures.'

"Mr. Berliner was born at Hanover, Germany, in 1851 and came to the United States in 1870.

"In 1877 he discovered that a loose metallic contact in an electrical circuit transforms sound waves falling upon it into electrical waves in the circuit. The apparatus used in this discovery is on view in the United States National Museum. It consists of a soap-box labelled 'Old Brown Windsor Soap' made by the American Company of Philadelphia. Over a hole in the side of this box is nailed an iron diaphragm. Touching this diaphragm is a steel button fixed on the end of a common screw held in a cross-bar. Sound waves falling upon this diaphragm cause the electrical resistance of the contact between it and the steel ball to change, thus producing a variation in the current flowing in the circuit, which contains at a distance a telephone receiver. In this way Berliner transmitted speech electrically.

"Undoubtedly, Mr. President, this is the most famous soap-box in captivity, for from this simple apparatus has arisen the modern microphone, which is the heart of telephony and of radio-broadcasting.

"For this brilliant achievement as well as for his outstand-

ing development of the method for recording speech on discs which are used today on talking machines, The Franklin Institute is happy to honor the inventor, summa cum laude, with its highest award—the Franklin Medal, together with a Certificate of Honorary Membership.

"Mr. President, it is with the greatest pleasure I present to you Mr. Emile Berliner."

The Medal, Certificate and Certificate of Honorary Membership were then presented to Mr. Berliner, in the following terms: "Mr. Berliner, it is particularly gratifying to The Franklin Institute to present to you the Franklin Medal and Certificate, and Certificate of Honorary Membership in the Institute, in recognition of a life-work of successful invention. We feel greatly honored in having you with us today and hope that you will continue in health for many years to come."

In accepting the honor, Mr. Berliner said: "Mr. President, officers and members of the Board, Committees, and The Franklin Institute: I highly appreciate this great honor and I want simply to state for myself that I bow to the memory of Benjamin Franklin. I greatly value the medal which you have presented."

To Dr. C. T. R. Wilson, Cambridge, England. Dr. James Barnes, sponsor.

The President called upon Dr. Barnes.

Dr. Barnes: "Mr. President: The Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts is unanimously of the opinion that a Franklin Medal be awarded to Charles Thomson Rees Wilson of Cambridge, England.

> "'In recognition of his numerous pioneer contributions to atomic physics, especially for his studies of condensation nuclei and his development of a method of photographing their tracks and for the vital importance of these studies to our knowledge of atomic structure and quantum mechanics.'

"Doctor C. T. R. Wilson, Jacksonian Professor of Natural Philosophy in Cambridge University, England, was born at Glencorse, Scotland, in 1869. The list of his honors and

degrees is a long one, including a Fellowship in the Royal Society and the Nobel Prize.

"He discovered that when air which is saturated with water vapor is ionized by x-rays and then suddenly cooled by an expansion, a smaller expansion is required to make a cloud form about the negative than about the positive ions. It was this discovery that enabled Sir. J. J. Thomson to determine that important scientific constant, the charge on the electron.

"He was the first to develop a method for exhibiting many of the properties of electrons, ions and x-rays by photographing their tracks through super-saturated water vapor. Some of the photographs showed a sharp deviation of beta-particles through large angles up to 180°. These are due to the close approach of the beta-particle to the nucleus of an atom. It was these observations together with the result of the scattering of alpha particles in passing through thin metal sheets that led Sir Ernest Rutherford to suggest his theory of atomic structure—a theory which to date is the one giving the greatest satisfaction. The photographs also showed that short range electrons were ejected by x-rays nearly along the direction of the primary ray. Their direction and range and the value of the minimum frequency of the radiation which is required to produce them are in agreement with the suggestion of Doctor A. H. Compton that a single electron may be effective in scattering a quantity of radiation and in so doing obeys the laws of quantum mechanics.

"Professor Wilson has also contributed valuable observations on atmospheric electricity.

"He is one of the leading authorities in experimental physics. For sheer intellectual effort and outstanding technical skill in the most fundamental regions of modern scientific work it may truly be said he is peerless.

"As you well know, Mr. President, the first President of The Franklin Institute, James Ronaldson, was born in Scotland; our late President, William Eglin, was also born in Scotland. On our membership list and on our committees are Scotchmen and descendents of Scotchmen. Today we have honored one Scotchman; now we honor another who also is unable to be with us in person. However, a most distinguished diplomat, His British Majesty's Ambassador to the

United States, who, although not Scotch, was born within sight of the Scottish border in Cumberland County, has done us the honor of coming here today to receive on behalf of Professor Wilson the Franklin Medal and Certificate of Honorary Membership. We highly appreciate this courtesy.

"Mr. President, I have the honor and pleasure of presenting to you His Excellency the Right Honorable Sir Esme Howard."

The Medal, Certificate and Certificate of Honorary Membership were presented to Sir Esme Howard, the Ambassador, in the following terms: "Professor Wilson, in acknowledging the award of the Franklin Medal to him, expressed his great regret at being unable to be present in person, He is, however, admirably represented by His British Majesty's Ambassador to the United States, Sir Esme Howard, who has graciously consented to be with us today to receive the Franklin Medal and Certificate and Certificate of Honorary Membership in the Institute, in behalf of Professor Wilson. Your Excellency, I am pleased to present these symbols of honorable consideration to you, with the request that you forward them to Professor Wilson with our compliments.

"Ladies and Gentlemen, the Ambassador from Great Britain to the United States."

In receiving the award on behalf of Professor Wilson, the Ambassador said: "Mr. President, Members of the Franklin Institute, Ladies and Gentlemen: I deeply regret that my distinguished fellow countryman—although I was born south of the border I venture to call him so—could not be here to receive directly from your hands this great honour which has been conferred upon him. I fear, after hearing all that has been said about his labours, I am entirely unworthy to take his place. All I can say is that last Sunday I heard a sermon in which the preacher defined faith as 'taking God at His word.' Now, Mr. President, when it comes to understanding electrons, ions, nuclei, and such mysterious things, all I can do is to take Professor Wilson at his word, and The Franklin Institute at its word! I can hardly say more.

"You will forgive me if I do not say much, but you will surely not expect me to talk about these mysterious matters.

"The Franklin Institute and the Royal Institute are, so to speak, sisters which, though wholly independent of each other, have much in common and have always been on the friendliest terms. They are the living embodiment of the truth that Science is international and has no boundaries or frontiers. Science exchanges for the benefit of all humanity the truths it discovers and it recognises scientific merit wherever scientific merit is to be found. It dispenses its honours with but one object in view—that of conferring distinction on those of mankind who most deserve it. The question of race, colour, religion or nationality does not come in here. Wars and rumours of wars hardly disturb the collaboration of scientists in their work for humanity at large and they set us an example which we might well follow if we in our hearts desire to establish the reign of international Law as opposed to Force.

"For these reasons, and as an Englishman, I feel peculiarly privileged in receiving on behalf of my distinguished fellow countryman, Professor Rees Wilson, this Medal which The Franklin Institute has been pleased to confer upon him, and I feel no doubt that this honour will be highly appreciated by his University, by all British Scientists and all his fellow-countrymen. In their name, as well as in his, I wish to tender to the President and Members of The Franklin Institute of Philadelphia our warmest and most grateful thanks."

Mr. Hayward: "Mr. Ambassador, on behalf of The Franklin Institute I thank you heartily for your great kindness in coming to us today. Your presence has added much to our enjoyment of this occasion."

The Secretary read the following letter and cablegram which had been received by him from Professor Wilson. He cabled: "Please express my sincerest regrets at not being able to be present at presentation and dinner and meet American friends." And the letter:

GLENCORSE,
56 STOREY'S WAY,
CAMBRIDGE,
March 24, 1929.

*Dear Dr. McClenahan,*

I thank you for your very kind letter informing me that the Board of Managers of the Franklin Institute have done me the great honour of awarding me the Franklin Medal.

Would you kindly convey to the Board my sincerest thanks and the expression of my high estimation of this honour. It is indeed a privilege to have my name added to the distinguished roll of Franklin Medalists.

I very much regret that other engagements here make it impossible for me to be present at the presentation of the medals on May 15th. It would have been a very great pleasure to me to have had that opportunity of meeting members of the Institute and other American friends.

Again thanking you for your very kind letter.

Very sincerely yours,

C. T. R. WILSON.

The first paper to be read was, "Vocal Physics," [1] prepared by Mr. Berliner and read by Dr. McClenahan, as Mr. Berliner was still rather weak from a recent illness.

The next paper was, "Some Thundercloud Problems," [2] written by Professor C. T. R. Wilson and presented by Professor John Zeleny, head of the Department of Physics, Yale University, who kindly consented to read this paper for us, at the suggestion of Professor Wilson.

At this point Dr. Sperry requested permission to speak. In commenting upon the paper he said:

"I only want to say how much The Franklin Institute should be congratulated on the accession of this remarkable paper to which we have just listened. It is apparent that we are here sitting at the feet of a great master. This is indicated by the ease with which he gives quantities throughout, whereas only qualities and generalities have heretofore been the practice.

"This paper clears up a very grave situation. It means that builders of aircraft, either heavier or lighter than air, no longer need fear that while in the air they will become 'thunderclouds' and either emit or receive charges of electricity.

"This conclusion arises from the fact that the thundercloud, according to the Cambridge professor's measurements, must be two cubic kilometres in size—almost a mile and a quarter square—in order either to emit or receive a charge of electricity.

"Compared with the smallest cloud that can act as a thundercloud, even the largest airplanes and dirigibles that

[1] See page 13.

[2] See page 1.

we can ever hope to make would become pygmies. The Graf Zeppelin, the largest aircraft now in existence, is about ten per cent of that dimension in length, and two per cent in diameter. The huge dirigibles which are now in course of construction for the United States Navy will not appreciably narrow the margin of safety.".

There being no further business, the meeting was declared adjourned.

## NOTES FROM THE U. S. BUREAU OF STANDARDS.*

### COMMERCIAL STANDARDS MONTHLY.

FOR over four years the progress of work in the field of commercial standardization has been recorded in a multigraphed periodical known as the "Commercial Standards Monthly." The demand for this publication has become so great (over 15,000 names are now on the mailing list) that permission has been obtained by the bureau to issue it in printed form.

In its new form the Monthly will contain brief statements of the current status of projects in the commercial standards field, commercial aspects and applications of the general standardization work of the bureau, references to similar work by other branches of the Federal Government, important achievements of national standardizing bodies outside the Government service, examples of waste elimination as affected by trade associations and individual companies, abstracts of articles which bear on national or regional standardization, brief accounts of work abroad where such is of interest to American business men, and certain miscellaneous items such as notices of new publications and investigations which are of interest.

As a printed publication the "Commercial Standards Monthly" will record the progress of work in its particular field much as the "Technical News Bulletin" covers the field of research and testing.

The first number of the Commercial Standards Monthly will appear about July 15. It is obtainable on a subscription basis from the Superintendent of Documents, Government Printing Office, Washington, D. C., at $1.00 per year to addresses in United States and its possessions, Canada, Cuba, Mexico, Newfoundland, and Republic of Panama; $1.25 to other countries.

* Communicated by the Director.

## TWENTY-SECOND NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

THE Twenty-Second National Conference on Weights and Measures was held in Washington, June 4 to 7, inclusive. The attendance numbered 250, delegates being present from 25 States and the District of Columbia. The sessions on the first two days were held at the bureau while those on June 6 and 7 took place at the Hotel Washington, the downtown headquarters of the conference.

The conference was opened with an address by Dr. George K. Burgess, Director of the Bureau of Standards and president of the conference. Doctor Burgess reviewed the status of Federal weights and measures legislation which has come before Congress since the last meeting of the conference, described weights and measures publications issued by the Bureau of Standards during the past year, and discussed the recent activities of the International Bureau of Weights and Measures, particularly as regards the international temperature scale, the alternate definition of the meter in terms of the red radiation of cadmium (1 meter = 1,553,164.13 waves), and the probable adoption of 20° C. (68° F.) as the standard temperature for shop standards of length. He also referred to the initial steps which have been taken to bring into agreement the electrical, thermal, and mechanical units.

On June 5 an address was delivered by the Secretary of Commerce, Hon. Robert P. Lamont, in which he pointed out the valuable work accomplished by the conference for the entire country through the exchange of ideas from the representatives of various states and cities. Without any regulatory power, and without in any way infringing upon the jurisdiction of the local governments, a high degree of uniformity in weights and measures regulation has been brought about.

One of the most interesting papers presented was that of Herbert L. Anderson, chief examiner of the Federal Trade Commission, who described what the commission is doing to eliminate unfair practices in weights and measures in interstate commerce. He spoke particularly of the elimination of packages correctly labeled, but of unusual weight such as 15 ounces instead of one pound, which have a tendency to

deceive the purchaser, misbranding of paint and textile materials, slack-filled packages, etc. Closer coöperation between the State and city weights and measures officials and the commission was urged by Mr. Anderson.

Another paper of special interest was that of Mr. John Holmes, vice president of Swift & Co., who described the unusual conditions which must be met by weighing devices in a large, modern packing plant. At every stage of the process from the receipt of the animals at the stockyards to the distribution of the finished product, scales are used, and the requirements are often severe. Many different types of scales are employed, depending upon the weight of material, time available for weighing, order of accuracy needed, etc. In some cases corrosion is a serious problem and constant attention is needed to maintain the scales at the high efficiency required.

Mr. B. W. Ragland, chief of the Bureau of Weights and Measures of Richmond, Va., described an unusual gasoline meter installation in a ramp garage, in which novel methods had to be employed to insure accuracy in the registration of meters on the different floors.

Papers presented by members of the bureau's staff included one on the repair of heavy-capacity scales (National Scale Men's Association Bulletin No. 1, written by Mr. C. F. Howkinson, president of the above association, who could not be present) by H. M. Roeser; identification by linear measurement, by W. H. Souder; a method for investigating short deliveries of fuel oil, by E. L. Peffer; the solution of air in gasoline, by O. C. Bridgeman; and the legal status of rules and regulations as established by decisions of the courts, by William Parry.

The conference adopted a number of amendments to codes of specifications and tolerances for commercial weighing and measuring devices which had been previously acted upon. Final action was taken in adopting specifications and tolerances on grease measuring devices, the code on this subject having been tentatively adopted last year.

At 12.30 P.M. on June 6, the delegates were received by President Hoover, and a special trip through the White House for the ladies of the party was arranged for the morning of the same day.

### CONFERENCE OF STATE UTILITY COMMISSION ENGINEERS.

THE Seventh Annual Conference of State Utility Commission Engineers was held at the bureau, May 31 and June 1. The conference was attended by 27 engineers representing 19 States and Two Provinces of Canada, Quebec and Ontario. That these conferences are becoming well known and appreciated is shown by the wide representation from the States, including California, Oklahoma, North Dakota, Minnesota, Iowa, Wisconsin, Alabama, Florida, in addition to the eastern States including four of the New England States.

The program was arranged by an executive committee of four: A. G. Mott, chief engineer, California Railroad Commission, chairman; I. F. McDonnell, chief engineer, Alabama Public Service Commission; Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners; and J. Franklin Meyer, Bureau of Standards, secretary. The following committee reports and technical papers were presented:

(1) Committee reports: Uniform types of rates and rate schedules, A. V. Guillou, assistant chief engineer, California Railroad Commission, chairman; Charges for fire protection, Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners, chairman; depreciation, A. B. Greene, telephone engineer, Railroad Commission of Florida, chairman; standard rural line construction and costs, J. Howard Mathews, assistant chief engineer, Illinois Commerce Commission.

(2) Technical papers: Street lighting rates, W. M. Black, electrical engineer, Pennsylvania Public Service Commission; rise and fall of prepayment gas meters—an obituary, and overhead wiring and radio antennæ, Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners; rural electrification, George Charlesworth, electrical engineer, Iowa Railroad Commission; long-distance manufactured gas transmission, M. T. Bennett, gas engineer, Wisconsin Railroad Commission; branch-line and switching transportation problems, R. H. Nexsen, deputy chief engineer, New York Public Service Commission; State regulation of common carrier motor bus, J. P. Wadhams, transportation engineer, Connecticut Public Utilities Commission; electric service rules, J. Franklin Meyer, Bureau of Standards.

The engineers attending these conferences have found them very useful and valuable, not merely from the committee reports and papers presented and discussed, but even more so from the personal contacts established and the opportunity afforded to compare experiences and interchange information as to the manner in which the engineering departments of the commissions handle their problems. The proceedings of the conference are not published, but a small number of copies of the committee reports and papers are available, and will be sent to commission engineers upon application, as long as the supply lasts.

The committee elected to take charge of the 1930 conference consists of Col. Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners, chairman; A. G. Mott, chief engineer, California Railroad Commission, vice chairman; George Charlesworth, electrical engineer, Iowa Railroad Commission; and J. Franklin Meyer of the bureau, as secretary.

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## SPECTRUM OF CHLORINE.

VALUABLE additions to our knowledge of the spectrum of chlorine, an element whose spectral characteristics have been practically unknown heretofore, and data tending to show that so far as we are now aware, chlorine does not exist in the sun, were made available to physicists and astronomers through a report published in the June number of the Bureau of Standards Journal of Research.

Several years ago, Prof. H. Kayser, of the University of Bonn, in reviewing the research work done on the spectrum of the gas chlorine made the statement that, in spite of all the investigations that had been made up to that time, the spectrum was still practically unknown. The cause for this situation lies in the fact that chlorine is a difficult element to observe spectroscopically. When an electric discharge is passed through the gas, at reduced pressure in a glass tube, it rapidly enters into chemical combination with the hot metal electrodes and the discharge tube soon becomes useless. This defect has been eliminated in an experimental procedure at the bureau, whereby a small portable chlorine generator is

attached to the discharge tube, thus permitting small amounts of the gas to be admitted to the tube to replace that which has combined with the electrodes.

With such a tube it was possible to produce the spectrum of chlorine for the long periods of time (up to 15 hours) necessary to photograph it in the regions where it had never previously been observed. As a result of this new investigation our knowledge of the spectrum has been extended from the wave-lengths visible to the eye in the violet and blue to those in the infra-red, beyond the limit of visibility, but capable of being photographed with specially sensitized plates.

Our modern theories of the structure of the atom enable us to predict the type of spectrum which the atom will radiate when it is losing the energy imparted to it, say, in an electric discharge. These new spectrum lines have been classified into spectral series and it is found that these conform in every detail, to the theoretical requirements. From this classification we may calculate the actual amount of energy required to put into the chlorine atom in order that it may radiate the various spectrum lines which characterize it. The chlorine atom has seven valence electrons and the amount of energy required to separate one of these from the atom proves to be 13 volts.

For some time astrophysicists have thought that some of the unknown lines of the sun's spectrum might be identified with those of chlorine when these became known. It is now possible to state that chlorine, if it exists in the sun, is not revealed by the presence of its spectrum lines among those of the Fraunhofer spectrum.

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### NEW METHOD FOR DETERMINING GASOLINE CONTENT OF NATURAL GAS.

THE bureau has developed a new precise method for determining the amount of gasoline present in an untreated natural gas, and the amount remaining in the treated gas.

Motor gasoline is produced in three ways: It is obtained from crude oil by straight refining methods; from petroleum distillates by so-called "cracking" processes; or from natural gas by compression-cooling, absorption and adsorption proc-

esses. Gasoline extracted from natural gas is a high grade condensate which is not marketed as a separate product, but is blended with cracked and refinery gasolines. Over 9 per cent. of the total amount of gasoline produced in this country is "natural gasoline," and its market value in 1926 was over $136,000,000.

Unfortunately, much of the natural gasoline present in natural gases is not recovered by present methods of recovery, and engineers are endeavoring to improve the operation of extraction plants. But in order to determine plant efficiencies, it is necessary to know how much gasoline occurs in an untreated gas and how much is left in the treated gas. Again, unfortunately, field and laboratory methods of test in common use are not capable of giving this information with sufficient accuracy.

The bureau has developed a method to meet this particular need of the natural gas industry. This method employs an isothermal distillation of the natural gas mixture and a system of recombination of various fractions, with measurements of their saturation pressures. It is accurate to within 10 gallons of condensate per million cubic feet of gas. In order to attain this accuracy with the small gas samples used, it was necessary to measure a volume of gasoline as small as 3 ten-millionths of a gallon and to employ temperatures as low as 347 degrees below zero (Fahrenheit).

A complete description of the method has just been published in the June number of the *Bureau of Standards Journal of Research*.

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**VOLATILITY DATA ON NATURAL GASOLINE AND BLENDED FUELS.**

THE growth of the natural gasoline industry, based on the recovery of highly volatile gasoline from natural gas, has led to the more widespread blending of natural gasoline with ordinary refinery gasoline, resulting in the marketing of many fuels which are more volatile than those hitherto studied in the investigation of gasoline volatility at the Bureau of Standards. In order to study those more volatile fuels, an apparatus was constructed for making measurements at temperatures down to 40 degrees below zero and experiments were made on a large number of gasolines at these low tem-

peratures. The general conclusion reached was in agreement with that found previously, that the volatility of any gasoline may be obtained from the usual distillation test used by the oil refiners.

Since addition of natural gasoline to a motor fuel increases the ease with which it will start an automobile engine, this work shows the refiner just how much natural gasoline must be added to ordinary gasoline to enable the motorist to start an engine under various climatic conditions. Ether is frequently used in very cold climates for starting airplane engines and some work was done on various mixtures of ether and aviation gasoline. This shows that whereas aviation gasoline, such as the Army ordinarily uses will start the airplane engine only at temperatures above zero, a mixture in equal parts of ether and gasoline should permit starting at about forty below zero. Ether-gasoline blends are desirable only for starting since the addition of ether to gasoline greatly increases its tendency to knock.

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### FIRE HAZARD TEST OF WOODEN LABORATORY TABLE.

FIRE hazard tests on a wooden laboratory table were made by the bureau at the request of the Board of Education and the Fire Department of the District of Columbia.

In selecting laboratory equipment for the new McKinley Technical High School, the question of the fire hazard of wooden tables was brought up by the Fire Department and a complete table which had been in use for several years in one of the schools was submitted for test. A Bunsen burner was overturned on the top of the table and the flames were allowed to spread or burn themselves out without interference. Five separate tests were made under conditions as nearly representative as possible of those that might occur in actual use. The entire table was consumed by the flames during the last test. Flame penetration tests were made on several small specimens of yellow pine and maple to determine the relative rate of burning of the two woods.

The fire hazard of wooden laboratory tables is dependent upon the design and the conditions of use. The least hazardous type of table would be one without reagent rack or drawers.

In the tests made representative of this type flames from the burner charred a hole in the top but did not spread to any appreciable extent beyond the edge of the burner flames. When books and papers were placed on the top and the flames allowed to impinge against them, the spread of the fire was greater and a considerable portion of the corner of the table was burned. Several embers of a size sufficient to ignite a combustible floor dropped from the table.

The most hazardous type of table would be one with a reagent rack and a stack of drawers underneath. While tests representative of the one with a reagent rack were not made, one was made in which the burner flame was directed downward on the table top directly above a stack of drawers. After the flames had burned through the top, the light wood of the drawers ignited and the flames continued to spread until the entire table was completely consumed.

The flame penetration tests indicated that pine table tops did not constitute a greater hazard than maple table tops.

The tests showed that wooden laboratory tables without drawers beneath or reagent rack, books or other combustible materials on top, do not present a serious fire hazard, particularly where placed on incombustible floors.

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## SPOTTING OF PLATED OR FINISHED METALS.

Many electroplated products, especially those that are plated with brass, or are given an "oxidized" finish, show a tendency for the development of dark, unsightly spots on the surface. This defect, commonly known to the platers as "spotting out," has at times proven very serious in certain industries, such as the manufacture of builder's hardware. The American Electroplaters' Society, composed of foremen electroplaters, collected from their members and from firms engaged in plating, funds for researches on electroplating at the Bureau of Standards, and selected "Spotting out" as the first problem for study.

The investigation has shown that there are two entirely distinct types of spotting. The "crystal spots" appear as dark radiating crystals upon metals that have a finish of copper sulphide (the so-called "oxidized" finish), and that

are subsequently lacquered. The "stain spots" appear principally upon cast metals, in the form of irregular areas of variable color.

The crystal spots are caused by the absorption of minute amounts of sulphur or sulphur compounds from the surroundings. Free sulphur (which may be used in certain plant operations), rubber bands, or wrapping paper or cartons containing small amounts of sulphur may cause this defect to develop. The only effective remedies are (1) the application of a lacquer which is most nearly impervious to sulphur; (2) the application of a very thin film of grease to the lacquered surface, and (3) the use of wax paper for wrapping the articles.

The stain spots result from the presence of minute pores in the metal, and the absorption in these pores of chemicals, either acid or alkaline, during the operations of cleaning and plating. When such articles are subsequently exposed to an atmosphere with high humidity, moisture is absorbed by the materials in the pores; which then exude and stain the surrounding metal.

Some improvement can be made by using less porous castings, and by allowing the chemicals to "spot out" from the pores before the final finishing. The most effective remedy is the application of such lacquers as have been found to retard or prevent the spotting. Lacquers submitted by many manufacturers were tested, and some were found to be much more effective than others. Additional studies by lacquer manufacturers will no doubt lead to further improvements.

A more complete account of this investigation has just been published in the June number of the *Bureau of Standards Journal of Research.*

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## REFERENCE LABORATORY FOR PORTLAND CEMENT.

AN important recent development is the establishment at the bureau of a reference laboratory for the testing of Portland cement, calibration of machines and instruments used in cement testing, and the training of men for commercial cement testing laboratories.

The new laboratory is supported jointly by the American Society for Testing Materials, and the Federal Government.

Its work is under the immediate supervision of P. H. Bates, chief of the clay and silicate products division of the Bureau of Standards.

The establishment of this new laboratory is the outgrowth of a plan originally formulated by the cement committee of the American Society for Testing Materials. Mr. Frederick W. Kelly, President of the North American Cement Corporation, as spokesman of the cement industry, addressed a letter to Mr. Bates, chairman of the cement committee of the A. S. T. M., on September 15, 1928, calling attention to the need of such a laboratory. In this letter Mr. Kelly said,

> "There are produced annually in the United States about 170,000,000 barrels of Portland cement. Substantially all this cement is made to conform to the Standard specifications for Portland cement which have been adopted by the American Society for Testing Materials, by the U. S. Government Departments and by the principal users of portland cement in the United States.
>
> "It is necessary that all this cement be tested to make certain that it does conform with the standard specifications, and it is important that such tests be made to insure the integrity of the structures in which the cement is used. It is of vital importance to both the user and the manufacturer of cement that the tests be accurate, and that the results of tests on the same sample by two laboratories be the same.
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> "There are in the United States today probably 300 cement testing laboratories. Several series of carefully conducted tests have shown a lamentable lack of concordance in the results obtained even among the best of them. Differences of 100 per cent. in results are not unusual. This introduces a most undesirable element of uncertainty into both the technical and the commercial ends of the cement industry, and is interfering with its development.
>
> "Printed information and instructions have been made available to all interested in an unsuccessful effort to secure better results. It is believed that personal inspection and instruction are needed to secure a proper appreciation by all laboratories of the importance of machine

calibration and exact compliance with specified conditions and methods. There is today no recognized authority equipped to give this inspection, instruction and advice.

"We propose to establish at the U. S. Bureau of Standards at Washington, a fellowship to be known as "Reference Laboratory for Standard Cement Testing." Under this fellowship, establish a laboratory with apparatus and personnel capable of making tests of Portland cement in strict conformance with the specifications. This laboratory staff to be prepared to instruct on proper methods of making tests and maintaining testing equipment, also to calibrate all equipment submitted by laboratories as purchasers or by manufacturers of said equipment."

As the result of this letter the details were worked out for the establishment of the desired laboratory under the Bureau of Standards research associate plan. The staff will consist of five experts, three of whom are already at work. This laboratory staff is prepared to give instruction on established methods of testing, and on the proper maintenance of testing equipment, and will also calibrate such equipment submitted by purchasers or manufacturers.

Tests will be made of Portland cement in strict conformance with the standard specifications and tests of the American Society for Testing Materials. For the present, it is planned to confine the work to physical testing.

The instruction to be given by the laboratory staff will be of two kinds, one in the laboratory in Washington and the other in the field.

"One: In Washington detailed instruction will be given in the making of test specimens and in the methods of testing. Instruction will also be given in the maintenance of testing equipment and in checking the calibration of equipment.

"Two: In the field the instruction will consist principally of criticism of methods and conditions noted in each laboratory visited, and suggestions will be given for improving them. At the same time testing equipment in the laboratory visited will be calibrated where possible and instruction given in proper maintenance of equipment.

"The service will be available upon application only and

will be rendered as nearly as possible in the order in which applications are received. Instruction in Washington may be expected to occupy two or more weeks, depending upon the aptitude of the men sent for training.

"The schedule of the laboratory representatives giving instruction in the field, must obviously be arranged by routes to avoid unnecessary traveling. A couple of days only can be allotted to each laboratory on each visit.

"Application for service should be made to

Cement Reference Laboratory,
c/o Bureau of Standards,
Washington, D. C."

It is the intention of the laboratory to issue certificates covering machines tested by it. These are all to be issued from Washington, and the fees charged for these services will be in accordance with the schedules for similar work now in force at the bureau. The money obtained will be deposited in the United States Treasury and will not be available for expenditure.

A special committee of the main committee on cement of the American Society for Testing Materials has been appointed to coöperate with the Bureau of Standards in conducting the work of the reference laboratory.

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### IMPROVED CHINAWARE TESTING MACHINE.

A MODIFIED impact machine for chinaware has been designed and built at the bureau to obviate certain difficulties encountered in the use of a similar testing machine specified in the United States Government Master Specification for Vitrified Chinaware, No. 243a.

The modified testing machine, as was the specified, is a pendulum apparatus. The modified type machine has only one steel cylindrical hammer ($3\frac{1}{2}$ inches long by $\frac{5}{8}$ inch diameter) weighing 5 ounces and suspended by 8 piano steel wires (0.01 inch in diameter). Because of its manner of suspension this pendulum swings in a vertical plane in an arc having a 24-inch radius, thus eliminating one of the objectionable features of the specified machine. One face of the new hammer is a spherical surface ($\frac{1}{2}$ inch radius) used to make impact tests, while the other is a cylindrical surface ($\frac{1}{2}$ inch

radius) used to make chipping tests. In using the specified machine it was necessary to use hammers of different size, shape, and weight for each test.

A steel scale which is a 90° segment of a 24-inch radius circle is fastened by two rigid arms to the supporting frame at the lower end of the arc through which the pendulum swings. The scale is graduated in divisions representing fractions of a foot-pound. Notches, each one representing an increment of 0.01 foot pound are cut into the scale to hold a pendulum releasing device in position. The specified machine used two scales (10 inch radius), one for each hammer, fastened to the frame at the upper end of the pendulum. The larger scale of the modified machine obviously has the divisions farther apart and is therefore much easier to read than the scale of the specified machine. The pendulum and scale of the modified machine may be raised or lowered by means of a threaded rod and two hand wheels.

The cast iron base plate, upright casting, the steel ring, and triangular blocks are essentially the same as used on the specified machine; however, the upright casting is more quickly moved by means of a threaded rod and crank in the modified machine.

In order to make a comparative study of the specified and modified machines, 33 brands of chinaware were received from 28 manufacturers and importers and tested for impact and chipping on both machines. The samples represented 28 different brands of domestic and five of foreign-made ware. From the data it appears that there is practically no difference in the values obtained on the specified and modified type machines.

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### CHANGE OF VOLUME DURING USE OF BURNED CLAY BODIES.

THE Columbus branch of the Bureau is conducting an investigation of the change of volume of burned clay bodies resulting from the autoclave treatment. Throughout the investigation a steam pressure of 150 lbs./in.$^2$ has been used. Semi-vitreous bars burned to cone 5+ were first studied by subjecting them to six autoclave treatments for one hour. Before each measurement the bars were dried for 24 hours at 110° C. The average increases in length were as follows: At the end of the first treatment, .089; second treatment, .108;

third treatment, .127; fourth treatment, .145; fifth treatment, .159; sixth treatment, .158 per cent., respectively. Weight changes studied indicated a similar rate of increase.

The effect of pressure without heat or water was studied by subjecting the glazed specimens to a pressure of 150 lbs./-in.$^2$ with compressed $CO_2$. No crazing resulted except when the glaze was very thick and then only a few craze cracks appeared. Heating at 185° C. produced no permanent increase in length, nor was any change obtained with a combination of heat and pressure without water. This indicates that the changes in length result from the presence of water.

The autoclave treatment, followed by cooling under steam pressure, gave a much greater increase in weight than did cooling under air pressure. However, the length changes were approximately the same in both cases.

It was found that the purely physical effect of filling the pores of the specimen with water was a minor factor in causing an increase in volume.

The bars which had previously been given six successive autoclave treatments were dried at 110° C. for a total of 40 days with measurements taken at different times. The average length in terms of the original was: At the end of one day drying, 0.158; 9 days drying, 0.109; 13 days drying, 0.095; 20 days drying, 0.076; 33 days drying, 0.057; and 40 days drying, 0.057 per cent. There is practically no change after 33 days drying. A study of weight changes gave similar results except that the loss was much more rapid and became practically constant from 13 to 20 days. Thus, there is a lag of the volume change as compared to the weight change.

Several bars were next subjected to the action of various liquids at elevated temperatures. The liquids used were all immiscible with water but were heated at nearly their boiling point for from two to four hours before the bars were put in, thus driving off any small amount of water which might have been present. A reflux condenser set-up was used, and the changes in length noted on treatment for several hours. With all the liquids used (paraffin, xylene, kerosene, and petrolatum) a positive increase in length was obtained in *every* case. These data strongly point to the probability that the change in length is not the result of hydration.

**A Substitute for Water Vapor in Wilson's Cloud Chamber.** K. PHILIPP. (*Zeit. f. Physik*, 53, 100.) With the passage of time Wilson's cloud method has grown to have greater and greater importance. By it the path of an alpha particle or other corpuscle in damp air is made manifest by rapidly expanding the volume. The space thus becomes supersaturated with water vapor and water deposits on nuclei that are portions of atoms resulting from collisions with corpuscles. The path of a particle is marked by a line of cloud. "Thus it is possible to make visible the consequences of a collision between an alpha particle and a hydrogen or a nitrogen atom and to examine whether the blow was elastic or not, and whether it led to the wrecking of the atom that was struck." In his search for the disintegration of atoms Holoubek modified the cloud method so that it showed, not the actual course of the impact, but the hydrogen particles broken away from atoms. Care was needed to exclude the possibility of such H particles being derived from the $H_2O$ vapor present. It seemed desirable, therefore, to replace the water by some liquid containing no hydrogen. The author has found carbon tetrachloride, $CCl_4$, to be entirely satisfactory. A solution of crude rubber in this liquid was introduced into the expansion chamber and spread on certain of the surfaces there. Upon drying this produced a layer of rubber that both absorbed and gave out $CCl_4$ vapor with readiness. For measurements on the range of particles the use of $CCl_4$ has an advantage over water. A disadvantage lies in the need of increasing the relative volume to a greater extent than when water is used in order to bring about condensation. This drawback can, however, be avoided by substituting argon for air in the expansion chamber.

G. F. S.

## NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

### THE REACTION OF CELLULOSE WITH PHENYLHYDRAZINE ACETATE.[1]

C. J. Staud and H. LeB. Gray.

THE method used by Vignon in studying the reaction of cellulose with phenylhydrazine acetate was modified and more accurate results are claimed. The effect of time of heating of cellulose with phenylhydrazine acetate was studied, and a curve reaching the horizontal after sixteen hours was obtained. Heating was done on a steam bath. It was found that Standard Cellulose contained 0.03 to 0.06 per cent. nitrogen after heating with phenylhydrazine acetate, and modified celluloses contained as high as 0.74 per cent. nitrogen. A general correlation between copper numbers and the nitrogen content of cellulose heated with phenylhydrazine acetate was found. In previously published work H. LeB. Gray and C. J. Staud (*Ind. Eng. Chem.*, **19**: 854) showed that alkali treatment of cellulose reduced the copper number; the same was found to be the case with regard to reactivity toward phenylhydrazine acetate.

### ON SOME VACUUM RECORDING GAUGES.[2]

K. C. D. Hickman

THERE has been no convenient instrument recording between ten millimeters and one hundredth of a millimeter of mercury. The present gauge covers this range and uses the tipping U-tube principle. Two interconnected mercury reservoirs are balanced on a fulcrum and maintained in equilibrium by a plunger working in a mercury dash-pot. One

* Communicated by the Director.

[1] Communication No. 376 from the Kodak Research Laboratories and published in *Ind. Eng. Chem.* (*Analyt. Edition*), **1**: 80 (1929).

[2] Communication No. 381 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer.* **18**: 305 (1929).

reservoir is connected flexibly to the vacuum line, while in the other a torricellian vacuum is preserved. Alterations of pressure disturb the balance of the system and move a pointer over a revolving drum. The principle is extended to various modifications, including a recording barometer of great range and sensitivity.

## NOTES FROM UNITED STATES BUREAU OF MINES.*

### LOW-FREEZING EXPLOSIVES.

THE art of producing low-freezing explosives has attained such development that there is no longer any real reason for putting a freezable explosive on the market, according to Dr. Charles E. Munroe, chief explosives chemist, United States Bureau of Mines. Frozen dynamite is a most objectionable and dangerous substance, for the frozen "sticks," or cartridges, tend to become rigid, Dr. Munroe points out. For loading into boreholes it is desired that the dynamite "sticks" shall be plastic so that they may be readily pressed into place. There is also the likelihood that rigid sticks may be ignited or exploded by friction against the walls if forced into a borehole. Frozen dynamite is difficult to detonate. Hence a grade of detonator which is quite capable of firing the unfrozen dynamite, and may be depended on to fire it, may not fire frozen dynamite at all, so that a misfire, with all its attendant evils, may result, or it may cause a partial explosion, or burning, giving off large quantities of poisonous fumes into a mine. Naturally such shots are not only a total loss, but, more than that, they are a source of additional expense and of danger. Consequently, users of dynamites have been strenuously warned against using frozen dynamite and advised to store their dynamite in such a manner as to prevent its becoming frozen, or if it became frozen, to thaw it before use.

In making dynamite, the nitroglycerin content is simply mixed with the other ingredients of the dynamite. In making explosive gelatin some soluble cellulose nitrate is dissolved in the nitroglycerin. In neither case does the nitroglycerin undergo any chemical change. It still retains all its properties, among which is its capacity to freeze at 56° F. Hence the dynamites, explosive gelatins and gelatin dynamites will freeze by exposure to about 56° F. because the nitroglycerin in them freezes, unless prevented by some special protection.

* Published by permission of Director, Bureau of Mines.

Since in the higher altitudes, and the higher latitudes of the temperate zones, where dynamites are most largely used, 56° F. is not uncommonly reached during nearly one half the year, the freezing of dynamite was common and thawing was largely resorted to, but, because of many circumstances, it proved to be a most delicate operation and gave rise to many serious accidents. It is probable that in the many lists of accidents from explosives, published during the last 25 years of the last century, there was no one cause of accidents more frequently cited than that of "attendant on thawing explosives" and though the total number of casualties may have been less than those due to mine explosions, or explosions in transportation, because few persons were likely to be about where the thawing was done, yet the actual number was very large.

As has repeatedly been found true in the development of many inventions, all this time simple means for the prevention of dynamite freezing were right at hand. The principle was well understood and widely applied, even in domestic operations. And when the method was worked out and successfully applied to dynamites it was so obvious as to excite wonder it had not been applied years before.

The principle was made use of in freezing ice cream mixtures where a lower temperature than the freezing point of water was sought and this was obtained by dissolving common sea salt in water, preferably frozen water.

It is common knowledge that when sea salt is dissolved in water the temperature of the liquid falls below the freezing point of water and that a lower temperature is required to freeze this salt water than is required to freeze fresh water. A great variety of other inorganic salts, such as potassium carbonate, calcium chloride, ammonium chloride and others have been similarly observed to cause a fall in temperature as they dissolve in water, each to its own point, some of them producing very low temperatures, and in each case the freezing point of the solution thus formed was proportionately low. Further observations demonstrated the fact that this behavior was not confined to water but extended to many liquids, and that it was not confined to inorganic salts but that it extended to many organic compounds.

That this is a principle of very wide application became apparent, but its use for the reduction of the freezing points of explosives came about rather by chance observation than through the systematic application of the principle.

By the beginning of the present century the explosives industry had attained large proportions. It was looked upon as a very profitable industry and many inventors were inspired to discover new explosive substances or to prepare new explosives combinations that they might share in this prosperity. About 1902 much interest began to be taken in the use of the trinitrotoluenes as military explosives, especially for H. E. shell. In the nitrating of toluene to prepare their desired products a considerable amount of tarry liquid residue was produced which the manufacturers were ready to dispose of at almost any price, and as it was cheap, apparently abundant, and possessed some moderate explosive qualities, the thought occurred of incorporating some of it into dynamite dopes. The resultant dynamite developed good qualities and in its use it was observed that it did not freeze under the conditions when other dynamites in use froze. It was not long after this that low freezing dynamites, designated as L. F., and containing "*liquid nitrotoluenes*" as a component, appeared in the market.

With the outbreak of the Great War, the nitration of toluene became so perfected that the "*liquid nitrotoluenes*" were no longer available for use in dynamites. Moreover a growing shortage of glycerin necessitated the use of substitutes. In this event sugars, such as cane sugar and glucose, were dissolved in the glycerin and nitrated with it and the sucrose and glucose nitrates, thus produced, were found to depress the freezing point of the "nitroglycerin." Later polymerized glycerins, in which the residues of two or more molecules of glycerin had coalesced to form larger molecules, were dissolved in the glycerin and nitrated with it, the nitrated polyglycerins serving admirably to depress the freezing point of the nitroglycerin.

The latest depressant for use, and the one now most largely used, is ethylene glycol dinitrate. Its introduction was determined to an extent by economic reasons, but it serves well the purpose and possesses additional character-

istics of value. The ethylene glycol, which is mixed with the glycerin before nitration, is synthesized from natural gas and there is every reason to believe that the available supply will prove abundant for many years hence.

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## CONSUMPTION CHANNELS OF QUICKSILVER.

IN contrast to ordinary metals, quicksilver is often sold directly by the producer to the consumer, and thus the uses of the metal are of direct interest to the producer. In the past, economic conditions and doubt in the minds of the producers as to the future of the metal have caused production in this country to be subject to violent fluctuations. In order to obtain comprehensive information on the amounts of the metal used by various industries, so that some estimate of future needs might be made available, the Pacific Experiment Station of the United States Bureau of Mines, in coöperation with the University of California, has been conducting an economic survey of this industry, and reliable data concerning the channels of consumption have been obtained for the first time in this country. Consumers of quicksilver have coöperated generously in furnishing information concerning their requirements, so that it has been possible to account for more than 30,000 flasks used during the past year. The present market value of this material in the unrefined form would be between $3,500,000 and $4,000,000. Various individuals have estimated a domestic consumption of from 32,000 to 35,000 flasks.

One of the surprising factors disclosed by the survey is the relatively large proportion of quicksilver used for scientific and technical instruments. The declining and soon nearly negligible consumption of quicksilver for amalgamation processes of recovering gold was formerly a large use, but has been more than outdistanced by the use for scientific and technical instruments. Modern industry has turned more and more to scientific and often automatic control methods in its processes, and because mercury is a liquid metal at ordinary temperatures, it has here a unique field of usefulness. To have faith in the future of modern industry is to have confidence in the future of quicksilver.

Many attempts have been made to find substitutes for the mercury fulminate used in blasting caps and ammunition. Manufacturers have long threatened to use such substitutes at times of high quicksilver prices, but it seems significant that the use of the metal for explosive caps has not decreased during times of high prices. Bridges, dams, subways, mines, and all other structures requiring explosives will continue to be built and will probably continue to take their toll of quicksilver.

Pharmaceuticals, chemical manufacturing processes, Neon and mercury lights, pigments and cosmetics, and the electrical industry are diverse uses showing steady consumption. Mercury-containing disinfectants for seed treatment are gradually being replaced by cheaper substitutes. To produce more kilowatts per ton of coal, attempts are being made to use mercury boilers in conjunction with steam boiler plants, and the technical difficulties are being overcome. It seems not impossible that the power plant of the future may require large amounts of quicksilver to enhance its mechanical efficiency.

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### A PARTIAL EXPLANATION OF THE HEIGHT OF IRON BLAST FURNACES.

The extent of preparation of stock in the upper part of a blast furnace, a factor affecting the economy of the process, depends upon the amount of contact between the gas stream and the solid charge. Time of exposure of the stock to the furnace gases, or what is generally called time of stock in the furnace, is some measure of the extent of preheating all of the stock and the reduction of the ore before reaching the lower part of the furnace. However, due to the fact that the gas does not flow at a uniform rate in all sections of the furnace, the time of exposure to the furnace gases is not a satisfactory index of gas-solid contact.

In addition to irregular gas flow, the North Central Station of the United States Bureau of Mines, in coöperation with the University of Minnesota, has found that the stock does not settle at a uniform rate in all parts of the furnace. The observed rate of stock descent near the wall in a 700-ton furnace was approximately one-third faster than the flow in

the center of the column. Over the iron notch the stock descended at a faster rate than along the periphery or in the center of the column. Variations in rate of stock descent as well as irregularities in gas distribution militate against gas-solid contact through which the process is carried forward.

If hearth diameters continue to increase, the difference in the rate of stock descent in the center of the column and along the periphery will also increase. Sintering of the fines in Lake ores and improvements in size distribution at the stock line will improve gas distribution, but a change in the general shape of the furnace will likely be necessary to attain more uniform stock descent along the periphery as compared to the center of the stock column.

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### IGNITIBILITY OF COAL DUST BY GELATIN DYNAMITES.

GELATIN dynamite of various strengths has been frequently used in bituminous coal mines to break rock. A gelatin dynamite is not a "permissible" explosive as it will not pass the tests. While its ability to ignite gas is more or less known, the fact that it will also ignite bituminous coal-dust clouds in the absence of gas appears to be less common knowledge despite the fact that this has happened in commercial mines. An easy method of demonstrating this has been developed at the Experimental Mine of the United States Bureau of Mines, near Pittsburgh, Pa. A half stick of 30 or 40 per cent. gelatin dynamite is primed with a No. 6 detonator and loosely buried near the top of a pile of 10 or 15 pounds of fine coal dust. When the dynamite is exploded the coal dust is dispersed into a cloud and ignited by the flame of the explosive. The only precaution necessary to ensure success of the experiment is to place the dust so that it will be thrown into a suitable cloud in the air, a matter readily learned by experience. The same experiment made in the pit mouth of the mine with additional dust on adjacent shelves produces a spectacular explosion which flares out the portal vigorously.

These experiments prove the inference that is drawn from accidents in commercial mines; namely, that gelatin dynamites should not be used in the presence of bituminous coal dust.

# THE FRANKLIN INSTITUTE.

## COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of Stated Meeting held Wednesday, June 5, 1929.)*

HALL OF THE INSTITUTE,
PHILADELPHIA, June 5, 1929.

DOCTOR THOMAS D. COPE *in the Chair.*

The following reports were presented for final action:

No. 2844: Pulse Relay.

In certain diseases of the chest the ability to detect the disease in its early stages is of great importance. The x-ray is used for this purpose and in order that correct information may be obtained by its use, particular care must be taken that the exposure shall be made when the arteries bringing blood into the affected area are quiescent.

The minimum movement of the heart is during the diastole phase of the heart beat and the period of greatest quiescence in the lesion is at a definite short interval afterward.

Recognizing the need for a device that should automatically make an x-ray exposure at exactly the time of least action, Doctor Charles N. Weyl of the Moore School of Electrical Engineering, University of Pennsylvania, after a long series of investigations, developed the Pulse Relay for this purpose.

In this device the pulsation of the heart is transferred to the control apparatus by placing the cup shaped terminal of a tube over the carotid artery by means of which a pulse of air is transmitted through the tube. This pulsation operates a diaphragm at the other end of the tube which in turn controls the position of a mirror that in its normal position throws a beam of light on the side of a box containing a photo-electric cell. When the pulsation reaches the mirror it is pushed to one side and the beam falls upon the cell. When this takes place a series of operations is set up that results in the possibility of an exposure at a definite interval after the heart beat.

The actual exposure is controlled by means of a foot switch which the operator closes when the exposure is wanted.

This relay is in extensive use at the Phipps Institute where it is being used in making routine examinations of school children for the detection of incipient pulmonary diseases.

This report closes as follows: "In consideration of the ingenious adaptation of mechanical and electrical principles to the operation of an x-ray apparatus which has proved useful in the diagnosis of certain diseases in their early stages of development, the award of the Edward Longstreth Medal to Professor Charles N. Weyl, of the University of Pennsylvania, Philadelphia, is recommended."

No. 2884: Work of Mr. C. S. Chrisman in the Gas Industry.

Mr. C. S. Chrisman began his work with the United Gas Improvement Company in 1891 and remained with the Company in various capacities until his retirement in 1929. During these thirty-eight years he was Draftsman, Assistant to the Construction Engineer, Head of the Order and Production Department of the U. G. I. Contracting Company and Assistant Engineer of Tests, a position which he held from 1923 until he retired.

During the time of his connection with the Company he contributed many inventions and improvements to water gas apparatus. Among these are the divided flow dip pipe for washboxes; automatic oil spray; cone top shells for water gas generators; stock valve operating mechanism; lock joint fire brick lining; welded steel construction for water gas apparatus and the Chrisman cycle which results in a decided saving of fuel.

The Chrisman Down Run Process is a design applied to a carburetted water gas set by which all the gas made on the down run is taken trom the bottom of the generator and led to a point beyond the superheater, but ahead of the washbox, which causes the down run gases to bypass both the carburettor and the superheater.

It is known that the gases made on the down run leave the generator at a lower temperature than either the blast or the uprun gases and that this is below that required in the carburettor and superheater for efficient oil results.

Since these comparatively cool gases bypass the carburettor and superheater the withdrawal of heat from the checker brick is prevented and the correct temperature for proper oil fixing can be carried on with a decreased fuel consumption.

Inasmuch as the blue gas made on the down run bypasses the checker brick, it becomes necessary to inject all the oil during the up run.

This design, known as the Chrisman Cycle, has proved to be economical and about seventy-five installations have been put in operation.

Mr. Chrisman has been granted five United States Patents on gas apparatus and eleven applications are now in the Patent Office awaiting action, beside seventeen patents and applications in foreign countries.

This report recommends the award of the John Price Wetherill Medal to Mr. Charles S. Chrisman, of West Chester, Pennsylvania, "In consideration of his ingenious and economical improvements in the apparatus for and methods of gas manufacture."

The following report was presented for first reading:

No. 2899: Hardened Metallic Drive Screws.

GEO. A. HOADLEY,
*Secretary to Committee.*

## MEMBERSHIP NOTES.

### ELECTIONS TO MEMBERSHIP.

*(Stated Meeting, Board of Managers, June 12, 1929.)*

#### RESIDENT.

MR. FREDERIC W. BRILL, Manufacturer, J. G. Brill Company, Sixty-second Street and Woodland Avenue, Philadelphia, Pa.

DR. EDWARD C. HAINES, Chemist, George D. Wetherill Varnish Company, Haddon Avenue and White Horse Pike, Camden, N. J.

DR. WILLIAM STERICKER, Chemist, Philadelphia Quartz Company, 121 South Third Street, Philadelphia, Pa. For mailing: 13 Park Avenue, Swarthmore, Pa.

#### NON-RESIDENT.

MR. CHARLES W. BRODWATER, Pharmacist and chemist, 416 Main Street, Bradley Beach, N. J. For mailing: Box 41, Bradley Beach, N. J.

PROF. BERNARD F. DOSTAL, Professor of Mathematics, University of Florida, Gainesville, Florida.

MR. WILLIAM H. MASON, Engineer and Manufacturer, Laurel, Mississippi.

### CHANGES OF ADDRESS.

MR. J. C. BANNISTER, 24 West Palm Lane, Phoenix, Arizona.

MR. DEWITT D. BARLOW, 930 Woodland Avenue, Plainfield, New Jersey.

MR. CARL G. BARTH, Boyne City, R. R. 2, Michigan.

MR. CHARLES H. COLVIN, 210 Columbia Heights, Brooklyn, N. Y.

MR. IRVING H. CROWNE, Wico Electric Company, Springfield, Mass.

MR. MILTON W. DEISLEY, 556 Shoemaker Road, Elkins Park, Pa.

MR. E. S. HIGGINS, 353 Lodge's Lane, Bala-Cynwyd, Pa.

MR. H. W. MAJOR, Robesonia, Pa.

DR. EDWARD E. MARBAKER, Vice-President, Industrial Research and Engineering Company, 7325 Penn Avenue, Pittsburgh, Pa.

DR. WALTER M. MITCHELL, Lukens Steel Company, 1341 Market Street, N., Canton, Ohio.

MR. ALBERT W. MORRIS, 701 Morris Building, Philadelphia, Pa.

MR. EDGAR B. NICHOLS, Bell Telephone Laboratories, 463 West Street, New York City.

MR. HOWARD SELLERS, "Shadowbrook," P. O. Box 249, Wynnewood, Pa.

REAR ADMIRAL D. W. TAYLOR, 1914 Connecticut Avenue, N.W., Washington, D. C.

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## LIBRARY NOTES.

### RECENT ADDITIONS.

Allen's Commercial Organic Analysis. Fifth edition, Volume 7. The Vegetable Alkaloids. 1929.

American Electrochemical Society. Transactions 1928. Volume 54. 1929.

BUSH, VANNEVAR. Operational Circuit Analysis. 1929.

CARSON, JOHN R. Electric Circuit Theory and the Operational Calculus. 1926.

CREAGER, WILLIAM PITCHER. Engineering for Masonry Dams. Second Edition. 1929.

EDER, J. M., AND EDUARD KUCHINKA. Jahrbuch für Photographie, Kinematographie, und Reproduktionsverfahren für die Jahre 1921–1927. Bd. 30, III Teil. 1928.

FITZGERALD, GEORGE FRANCIS. Scientific Writings. Collected and edited by Joseph Larmor. 1902.

FOSTER, WILLIAM. Inorganic Chemistry for Colleges. 1929.

FOWLER, CHARLES EVAN. The Ideals of Engineering Architecture. First edition. 1929.

FRY, THORNTON C. Elementary Differential Equations. 1929.

GEERLINGS, GERALD K. Metal Crafts in Architecture. 1929.

GUERTLER, W., AND W. LEITGEBEL. Vom Erz zum metallischen Werkstoff 1929.

HURD, CHARLES DEWITT. The Pyrolysis of Carbon Compounds. 1929.

IMHOFF, KARL. The Arithmetic of Sewage Treatment Works. Translated from the German by G. M. Fair. 1929.

Jahresbericht über die Leistungen der chemischen Technologie für das Jahr 1927. 73 Jahrgang. 2 Abteilung. 1928.

KENNELLY, A. E. Electric Lines and Nets. Second edition. 1928.

KILBY, CLINTON MAURY. Introduction to College Physics. 1929.

MCCULLOUGH, C. B. Economics of Highway Bridge Types. 1929.

MCDONALD, PHILIP B. English and Science. 1929.

Manufacture of Pulp and Paper. Volumes 1–5. 1921–1929.

MATTHEWS, J. MERRITT. The Textile Fibers. 1924.

PRAGER, B., D. STERN, AND K. ILBERG, editors. System der organischen Verbindungen. Ein Leitfaden für die Benutzung von Beilsteins Handbuch der organischen Chemie. 1929.

Society of Automotive Engineers. S. A. E. Handbook. 1929.

Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Volume 13. 1928.

USHER, ABBOTT PAYSON. A History of Mechanical Inventions. First edition. 1929.

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## BOOK REVIEWS.

ELEMENTARY DIFFERENTIAL EQUATIONS. By Thornton C. Fry, Ph.D., Member of the Technical Staff Bell Telephone Laboratories, Inc. x–255 pages, illustrations, 8vo, cloth. New York, D. Van Nostrand Company, Inc., 1929. Price, $2.50.

Most of those who study differential equations do so in connection with a course at college or other institution of like grade. An occasional minority must learn from a textbook stimulated only by the desire to advance and aided by their own resource in overcoming the inevitable difficulties of a beginner in the absence of the helpful guidance of a teacher. The present volume which embraces the methods of solution of ordinary differential equations is especially well adapted to

the needs of the latter class of readers by the presence of a profusion of explanatory, illustrative, and appropriate philosophical matter. The work is, however, by no means designed exclusively for this type of reader. It is evolved, the author explains, from a set of mimeographed sheets of the Out-of-Hour Courses of the Bell Telephone Laboratories where naturally problems of transcendent type are of frequent occurrence. Not a few of the well chosen problems, and the exceptional clarity of the discussions are doubtless inspired by the author's close contact with analytical processes and their application in practice.

The author does not at once plunge into the development of a set of formal methods for the solution of differential equations but devotes fifty-seven pages to such an important prelude as continuity, differentiability, the significance of differential equations and their solution, and the origin of differential equations. This he supplements with a discussion of illustrations from mechanical, thermal and electrical phenomena. The student must have such information to achieve a true grasp on the subject, and he can obtain it in this way with a minimum expenditure of time and effort. An equally searching analysis of theoretical and practical difficulties is maintained in developing the methods of solution which follow. Adhering strictly to mathematical rigor in premise and deduction, the argument is carried on in simple direct language, notably in contrast with that economy of words often practiced by mathematical authors. Thus, referring to an artifice for the separation of variables he observes: "The reader will no doubt feel that this is a piece of trickery which is only likely to work on problems which have been hand-picked for the purpose. There is indeed a certain amount of truth in this reaction, for even when a suitable substitution exists it is not likely to be obvious. . . . "

The considerable number of examples of applications, which are sometimes of a geometrical, sometimes of a physical character, are collected into separate chapters, the two-fold object being to permit an uninterrupted flow of mathematical ideas and the inclusion of a greater number of examples than otherwise would be feasible. The graphical method of integrating simple functions and the integraph of Coradi are mentioned and analyzed at some length, the mechanical method having particular significance in view of the recent appearance of highly successful machines for that purpose. Operational methods which latterly have received a great amount of attention are duly considered. Though a bibliography is generally expected with a modern mathematical work, none is given in this one. The book is thorough, precise and in its mode of treatment stimulating to a desire for a mastery of the subject.

L. E. P.

ENGLISH AND SCIENCE. By Philip B. McDonald, Associate Professor of English, College of Engineering, New York University. 192 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1929. Price, $2.

Here at last is a prophet calling to us out of the wilderness of bad English that has been for some time spreading over the literature of American Science. Will his voice be heard or will it fall upon deaf ears? Most probably the latter. Some control of literary form is maintained in England but the "American language" knows no master. Every one does as he sees fit. There lies before the reviewer as he writes these lines, a small book, a grammar for French children from 10 to 12.

It contains several pages of permissible forms that have been specifically approved by the French Academy of Letters. Every public, parochial and private school in France will be informed of these and will loyally accept them. Not so in the United States. We are a free people. Shall bespectacled old pedants who have spent their lives studying Orthography, Etymology, Syntax and Prosody, be permitted to hold the free and holiday rejoicing spirit down to rules of form or pronunciation? Never! "Data is," "Who did you speak to," "These kind of things is troublesome." Everybody understands what is meant by such phrases. Why worry about Lindley Murray's opinions on the subject?

Turning to the book in hand, the reviewer must confess considerable disappointment. In many places the author seems to favor loose and even distinctly ungrammatical forms. Thus on page 152, "Whom are you speaking to?" is declared to be correct but stilted and bookish. Surely the proper criticism is that the form should be "To whom are you speaking?" There is nothing stilted or bookish in that; it is brief, direct and correct. The excessive use of "which" for "that" is properly disapproved, but the enginer is hoist with his own petard, on page 126, in the sentence, "The camera which I bought in Albany is broken," surely, "The camera that I bought, etc." is preferable.

It would require too much space to discuss the book fully; the reviewer is compelled to regard it as an insufficient treatment of an important problem in American literature, but it is not likely that anyone could do better. By the mingling of nations in the "melting pot," by the excessive encouragement of "practical" results in all fields, refinement of speech both as to form and utterance has been damaged beyond remedy. "Ephraim is joined to idols: let him alone."

The impression on the reviewer is that the book is somewhat a counsel of imperfection. A decided note is struck against "pedantry" and pedantry in this case seems to mean grammatical precision. The book is specially addressed to scientists. The main tendencies of modern science are toward minute accuracy and regularity. In chemistry the adoption of official methods of analysis and the manufacture of analyzed reagents have been characteristic developments. The great nations have established bureaus for standardization. The United States has inaugurated proceedings for bringing manufacturers of all types into closely restricted lines. The nineteenth century saw the full flowering and much fruiting of Kopp's fourth period in the history of chemistry—the era of quantitative analysis. The literature of science is safest in the hands of those who obey the rules of the language in which they write.

HENRY LEFFMANN.

INTRODUCTION TO COLLEGE PHYSICS. By Clinton Maury Kilby, Ph.D., Professor of Physics in Randolph-Macon Woman's College. vii–349 pages, 358 figures. New York, D. Van Nostrand Company, Inc., 1929. Price, $3.

As a reason for its inception the author desired to prepare a book which would provide sufficient general physics for a first year college course and no more. Emphasis has been placed upon the arrangement of the subject matter in order that the student may acquire the knowledge in the most efficient manner. The fundamental and more or less abstract concepts are introduced at the beginning of the course while the study of more interesting phenomena are reserved for that period initiated by the "vernal equinox" and usually heralded by a noticeable lessening in application to the studies.

The book is well supplied with figures and illustrations. Sufficient problems are added so as to insure a thorough understanding of the principles involved. These are prefaced by solved problems to serve as examples. The subject matter is set forth very clearly and in an interesting manner.

T. K. CLEVELAND.

THE PYROLYSIS OF CARBON COMPOUNDS. By Charles Dewitt Hurd, Associate Professor of Chemistry, Northwestern University, Evanston, Illinois. American Chemical Society Monograph Series. 807 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1929. Price, $12.50.

At first reading the reviewer thought that this title was merely a formal expression of the procedure of "cracking" now so familiar in the treatment of petroleum but on examination of the work the word pyrolysis is seen to cover a very much larger field applying in fact to all transformations of chemical substances through the agency of heat alone. Such changes are of course, as all working chemists know, in a great majority of cases decompositions sometimes very definite in character with the production of only two or three products each in appreciable and recognizable amount but in other cases extremely complex both as to the details of transformation and as to the products obtained. Decomposition for example of oxalic acid may be instanced among the simpler forms but the destructive distillation of coal and wood involves so many transformations that all details have not yet been ascertained. The author, however, in his preface calls attention to the fact that the word pyrolysis has a much wider significance than the instance of decomposition by heat, for the word decomposition carries with it always the formation of at least two substances. Heat may cause merely rearrangement, a definite instance of which is the transformation of ammonium cyanate into urea, discovered about a century ago and marking not so much the suggestion of such transformation as the breaking down of the distinction then held between organic and inorganic chemistry. The transformation is usually represented as a mere rearrangement but researches seem to show a somewhat more complicated action involving the production of another form of cyanate. The present volume deals directly with the phenomena of pyrolysis without direct attention to the influences of catalysts. Occasionally notice is made of such effects. The author states that frequently in these transformations it is difficult to distinguish catalytic and non-catalytic action. An interesting fact is stated that it is beginning to be thought that even the material in which experiment is being made has an influence on the chemical change. It is thought, for instance, different kinds of glass affect the results of experiments. In modern laboratory work, glass, quartz or porcelain are the materials usually employed. It is thought that their catalytic action is very slight. In large operations metals are mostly used and reference is made to a recent statement, that in cracking petroleum, chromium steel, aluminum or calorized iron should be used. Some other metals seem not to be so satisfactory. There is a report, for instance, of many experiments carried on a tinned iron tube which would have failed in the plain iron because of the tendency of liberated carbon to adhere to the walls of the latter. Some of these effects, however, may be ascribed to direct chemical affinity and not included in catalytic action.

The book in hand is one of the now large series of monographs issued under

the auspices of the American Chemical Society. It is much more bulky than most of those volumes but its size is due to the enormous amount of information which has been collected by the author and arranged in a very satisfactory form. The classification follows mostly that of the ordinary manuals of organic chemistry beginning with the open-chain hydrocarbons and taking up in separate chapters the important types and groups. The nature of the transformation is fully illustrated by structural formulas. An examination of the work will impress the chemist who has not paid attention to the subject with a vast amount of labor that has been given to this special phase of chemical change. It is true that very much of this research has resulted in industrial development and has been promoted by the necessity or expectation of new and valuable procedures in applied chemistry.

The work shows the same excellence of manufacture, editing and arrangement that has characterized the series to which it belongs.

HENRY LEFFMANN.

OPERATIONAL CIRCUIT ANALYSIS. By Vannevar Bush, Eng.D., Professor of Electric Power Transmission, Massachusetts Institute of Technology, with an appendix by Norbert Wiener, PhD., Assistant Professor of Mathematics, Massachusetts Institute of Technology. x–392 pages, illustrations, 20 x 13 cm., cloth. New York, John Wiley & Sons, Inc., 1929. Price, $4.50.

It has taken something like fifty years for Oliver Heaviside's inspiration of the operational method of analysis of circuit transients to come into extended use. Electrical science of his day made little demand upon mathematical power of that sort and only a select few, notably in the field of cable telegraphy, had occasion to study its capabilities. The rapid advance of physical science has finally commanded attention to this far-sighted work, and in the hands of mathematical physicists in many quarters the operational method is rapidly becoming interpreted by conventional rigorous procedure and brought into contact with engineering problems rare in the early days of electrical science but now of frequent occurrence. Within the last decade, a considerable number of periodical contributions and several texts have made rational derivations available. Doctor Bush takes another step towards bringing the subject into closer relation with engineering practice in presenting a deductive account of the fundamental principles of the process and its application to the analysis of the variety of circuits which occur in physics and in engineering. By far the widest application is to electrical circuits, but hydraulic, mechanical and other circuits are equally amenable to that method.

Being a process which has been evolved from a consideration of electrical circuits, a somewhat lengthy survey is made of the physical meaning of the differential equations which represent their fundamental characteristics. The unit function, the superposition theorem and the infinite integral theorem are discussed at length, being the leading principles employed in later establishing the Heaviside expansion theorem and a rigorous demonstration of the direct operational method. As the subject is expanded, the reader is introduced to the many ramifications, subtleties and refinements of the subject. These include interdependence between the Heaviside operational method, the theory of functions of a complex variable, and the expression by operational methods of functions represented by Fourier series. A cable problem illustrates how fractional-order derivatives arise and the discussion of the use of the gamma function in its inter-

pretation is interesting and illuminating. There is yet more in considerable volume; the process of expansion of operators in series as employed by Heaviside, a lengthy examination of operational expressions involving positive roots, a collection of special circuit problems and the methods and artifices that may be applied to their solution, and finally an outline of networks with variable parameters. The work is thoroughly documented, the references being given in footnotes. Besides the numerous test-problems which follow each chapter, there are, as is to be expected, numerous illustrative problems in the text. The appendix by Doctor Wiener is a general treatment of Fourier analysis and asymptote series.

The author states that he writes as an engineer rather than as a mathematician, but a spirit of mathematical rigor pervades the entire work and the reader who undertakes its perusal will be best served who has acquired a capacity for mathematical generalization with the accompanying facility in the use of mathematical processes.

L. E. P.

INORGANIC CHEMISTRY FOR COLLEGES. A textbook for students of second year chemistry. By William Foster, Ph.D., Professor of Chemistry in Princeton University. viii–837 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1929. Price, $3.90.

Within the compass of a little over 800 pages this book contains a very large amount of information on inorganic chemistry. In the preparation of such a work the principal difficulty is to determine what *not* to include. The field even of inorganic chemistry is now so extensive that it is almost impossible to so balance the selection as to give the student a satisfactory cross-section of the more important facts. Comparison of such a recent manual as the present with the older works will show the enormous development of physical chemistry. A phase of the science which was but briefly treated in the older manuals is now extensive enough to be a prominent feature. Physics has indeed been steadily absorbing inorganic chemistry and it seems as if it may some day force a separation of the workers in chemistry into two practically independent groups, those who pursue the physical phenomena of the science and those who apply themselves solely to its development. Analysis, synthesis and development of industrial applications constitute that part of the science which appeals to the mass of the community, the more abstruse phases, discussion of atomic structures, and transformations of atomic arrangement, colloidal phenomena, and other features of the progress of later years will have to be in great part ignored by the commercial analyst and the works-chemist. The person engaged in the laboratory of the department of health of a community or in the clinical laboratory of a hospital or in charge of the chemical problems of a great plant is bound to care very little as to whether Rutherford-Bohr or the Lewis-Langmuir structure of the atom is to be preferred. Such person deals only with definite results obtained by definite procedures with a definite reagent.

Notwithstanding this impending separation of theory and practice it is important that the beginner in chemistry should know its fundamental theories and some of its speculative views. It is a training through which everyone must pass who is preparing to be a chemist whether a worker or a teacher. This book affords a very excellent presentation of the later developments in theoretical

chemistry and also a large amount of data in the applications of it to the ordinary affairs of life. Details of manufacturing processes of analytic procedures must of course be left to the later period of study. The work is excellently written and well printed and also commendable for the low price at which it is sold.

HENRY LEFFMANN.

DEFORESTED AMERICA. By Major George P. Ahern. 79 pages, illustrations, 21 x 14 cm., paper. Washington, D. C., Deforested America, 1617 Rhode Island Avenue, 1928. Price, post paid, 20 cents.

Between the specific business interests of a large industry, and the economic interests of the country at large, with respect to the product of that industry, a marked divergence of view-point is to be expected. A scarcely better example of such a rule is to be found than in the consideration of the attitude of lumber-producing corporations as contrasted with the views of the proponents of the conservation of timber resources. The National Lumber Manufacturer's Association, on the one hand, proclaim that there is an abundant supply of timber and recommend the extended use of that widely applicable structural material both on account of its intrinsic merit and as a stimulus to commercial forestry. On the other hand the advocates of the public control of lumbering insist that only such a measure is capable of arresting forest devastation in America.

In a foreword to this account of our forest problem and recommendations for its effective solution, former Governor Pinchot points to the distinguished service of the author as an officer of the United States Army, and as a teacher and practical forester of note over a long term of years. "Major Ahern's success in forest conservation in the Philippines," he tells us, "was built on Government control of lumbering. That is and always has been the foundation of such success throughout the world." The plea for effective conservation of this indispensable commodity is supported by authoritative reports of legislative investigation in every section of the country, and the pamphlet should be read by everyone who appreciates the vital importance of providing for the maintenance of timber production not alone for future generations but for those of the near future.

LUCIEN E. PICOLET.

VOM ERZ ZUM METALLISCHEN WERKSTOFF. By Dr. W. Guertler and W. Leitgebel of the Metal Institute, Berlin. xxiii–426 pages, 170 illustrations and 30 tables, 8vo. Leipzig, Akademische Verlagsgesellschaft, m.b.H., 1929. Price, 32 marks.

"From ore to finished product" which is the title of this work suggests the familiar slogan of our American business houses "From factory to you," but the latter phrase refers to the alleged suppression of the middleman as a sufficient guarantee of cheapness. This work, however, deals with the many processes which are involved in the transformation of the raw material to the finished product and covers a great variety of procedures. As the authors say in their introduction, the present age is called industrial and the foundation of its existence is very largely the handling of the group commonly known as the baser metals. Outside of this class, so familiar to us in our daily life, is the group that the alchemists called the noble metals and in later times great importance has come to certain compounds

and forms of the group known as the rarer metals. The progress of invention and discovery has created demands for certain members of the latter group and in several cases has so stimulated search for their ores that great quantities have become available. In this way certain compounds that were only seen in the older laboratories in small specimens are familiar products of commerce and industry. This book does not enter upon a study to any great extent of the rarer elements but covers those which are extensively employed in ordinary life either as materials or as tools used in industry.

A treatment from this point of view will involve a discussion of ores as well as processes and properties of the finished material. A broad view of the nature of ores and of the relative abundance in the earth's crust is presented in an early chapter but many of the ores are described according to their physical properties, chemical composition, and crystalline form. The nature of alloys which now-a-days constitutes so large a part of metallic products is taken up in considerable detail. The chemistry of the transformation of ores into pure metal as well as the technology of the ores is also presented in detail. Many illustrations both microscopic and macroscopic aid in understanding the subject. Theoretical considerations are also given prominent form and many diagrams illustrate physical structure. The work, therefore, covers a special field and touches at many points the practical applications of metallurgy. It is indeed a very comprehensive volume crowded with important information carefully and thoroughly set forth. It is an excellent specimen of printing and the book has the agreeable quality that its pages lie open flat at every point. HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 301. Full Scale Tests of Wood Propellers on a VE-7 Airplane in the Propeller Research Tunnel, by Fred E. Weick. 23 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price, fifteen cents.

This investigation was made primarily to afford a comparison between propeller tests in the new Propeller Research Tunnel and flight tests and small model tests on propellers. Three wood propellers which had been previously tested in flight on a VE-7 airplane, and of which models had also been tested in a wind tunnel, were tested again on a VE-7 airplane in the Propeller Research Tunnel. The results of these tests are in fair agreement with those of the flight and model tests.

Tests were also made with the tail surfaces removed, and with both the wings and tail surfaces removed. It was found that the effect of the tail surfaces on the propeller characteristics was negligible, but that the wings reduced the maximum propulsive efficiency about 5 per cent.

Report No. 303. An Investigation of the Use of Discharge Valves and an Intake Control for Improving the Performance of N. A. C. A. Roots Type Supercharger, by Oscar W. Schey and Ernest E. Wilson. 9 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price, ten cents.

This report presents the results of an analytical investigation on the practicability of using mechanically operated discharge valves in conjunction with a

manually operated intake control for improving the performance of N. A. C. A. Roots type superchargers. The investigation was conducted by the staff of the National Advisory Committee for Aeronautics at Langley Field, Va.

These valves, which may be either of the oscillating or rotating type, are placed in the discharge opening of the supercharger and are so shaped and synchronized with the supercharger impellers that they do not open until the air has been compressed to the delivery pressure. The intake control limits the quantity of air compressed to engine requirements by permitting the excess air to escape from the compression chamber before compression begins.

The percentage power saving and the actual horsepower saved were computed for altitudes from 0 to 20,000 feet. These computations are based on the pressure-volume cards for the conventional and the modified Roots type superchargers and on the results of laboratory tests of the conventional type.

The use of discharge valves shows a power saving of approximately 26 per cent at a critical altitude of 20,000 feet. In addition, these valves reduce the amplitude of the discharge pulsations and increase the volumetric efficiency. With slow-speed Roots blowers operating at high-pressure differences even better results would be expected. For aircraft engine superchargers operating at high speeds these discharge valves increase the performance as above, but have the disadvantages of increasing the weight and of adding a high-speed mechanism to a simple machine.

Report No. 309. Joint Report on Standardization Tests on N. P. L. R. A. F. 15 Airfoil Model, by Walter S. Diehl. 20 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price ten cents.

This report contains the wind-tunnel test data obtained in the United States on a 36 by 6 inch R. A. F. 15 airfoil model prepared by the British Aeronautical Research Committee for international trials. Tests were made in cooperation with the National Advisory Committee for Aeronautics at the Bureau of Standards, Langley Memorial Aeronautical Laboratory, Massachusetts Institute of Technology, and McCook Field.

In addition to brief descriptions of the various wind tunnels and methods of testing, the report contains an analysis of the test data. It is shown that while in general the agreement is quite satisfactory, there are two cases in which it is unsatisfactory. Since the lack of agreement in the latter is probably explained by errors known to be inherent in the methods of determining and applying corrections in these particular tests, it is concluded that the agreement obtained is more a matter of technique than a wind-tunnel characteristic.

Report No. 310. Pressure Element of Constant Logarithmic Stiffness for Temperature Compensated Altimeter, by W. G. Brombacher and F. Cordero. 13 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price ten cents.

The usual type of altimeter contains a pressure element, the deflections of which are approximately proportional to pressure changes. An evenly divided altitude scale is secured by using a mechanism between the pressure element and pointer which gives the required motion of the pointer. A temperature-compensated altimeter was constructed at the Bureau of Standards for the Bureau of

Aeronautics of the Navy Department which contained a manually operated device for controlling the multiplication of the mechanism to the extent necessary for temperature compensation. The introduction of this device made it difficult to adjust the multiplying mechanism to fit an evenly divided altitude scale. To meet this difficulty a pressure element was designed and constructed which gave deflections which were proportional to altitude; that is, to the logarithm of the pressure. Mathematically, the logarithmic stiffness $S'$ of the element equals

$$S' = \frac{d \log_e P}{dy},$$

from which is derived the deflection $y$ for the change in pressure from $P_0$ to $P$

$$y = \frac{\log_e P - \log_e P_0}{S'}.$$

The element consisted of a metal bellows of the sylphon type coupled to an internal helical spring which was designed so as to have a variable number of active coils. This report presents a description of and laboratory data relating to the special pressure element for the altimeter. In addition equations which apply generally to springs and pressure elements of constant logarithmic stiffness are developed, including the deflection and the spacing between the coils in terms of the constants of the helical spring and pressure element. R.

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## PUBLICATIONS RECEIVED.

*English and Science*, by Philip B. McDonald. 192 pages, 12mo. New York, D. Van Nostrand Company, Inc., 1929, price $2.00.

*The Pyrolysis of Carbon Compounds*, by Charles Dewitt Hurd. American Chemical Society Monograph Series. 807 pages, 8vo. New York, The Chemical Catalog Company, Inc., 1929, price $12.50.

*Polar Molecules*, by P. Debye, Ph.D. 172 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1929, price $3.50.

*Inorganic Chemistry for Colleges*. A textbook for students of second year chemistry by William Foster, Ph.D. 837 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1929, price $3.90.

*Vom Erz zum metallischen Werkstoff Leitlinien und Rüstzeug der metallurgischen und metallkundlichen Wissengebiete*, von Dr. W. Guertler und W. Leitgebel. 426 pages, illustrations, 8vo. Leipzig, Akademische Verlagsgesellschaft m. B. H., 1929, price 32 marks.

*National Advisory Committee for Aeronautics*. Technical Notes: No. 303, Condensed data on the aircraft engines of the world compiled by C. S. Fliedner. 15 pages, illustrations, quarto. No. 305, Corrosion embrittlement of duralmin. VI. The effect of corrosion, accompanied by stress on the tensile properties of sheet duralmin by Henry S. Rawdon. 26 pages, illustrations, quarto. No. 306, Curves showing column strength of steel and duralmin tubing by Orrin E. Ross. 12 pages, illustrations, quarto. Washington, Committee, 1929.

## CURRENT TOPICS.

**The Change of Electrical Conductivity in Strong Magnetic Fields.** P. KAPITZA. (*Proc. Roy. Soc.*, A. 791.) The author has at his disposal a wonderful electromagnet capable of producing for a very short time a magnetic field of 300,000 gauss. He has already published the results of his investigation of the effect of this field on the electrical resistance of bismuth. He found that "the resistance of bismuth in weak fields increases in proportion to the square of the magnetic field, and in stronger fields follows a linear law, the increase of resistance being proportional to the magnetic field up to fields of 300 kilogauss." Other substances were discovered to resemble bismuth in their change of electrical resistance with the strength of the acting magnetic field. In consequence a survey of the elements on a large scale was undertaken. No less than 35 elements have been studied, viz., Li, Na, Cu, Ag, Au, Be, Mg, Zn, Cd, Hg, Al, Ga, In, Tl, C, Ti, Ge, Zr, Sn, Pb, Th, V, As, Sb, Bi, Ta, Cr, Mo, Te, W, Mn, Fe, Ni, Pd, Pt, and in addition two alloys. The substance under examination was placed in a Dewar flask containing liquid air or nitrogen or a mixture of solid $CO_2$ and ether. The flask was located between the poles of the electromagnet. Changes of resistance could be measured to one-half or one-quarter per cent. This was adequate as the application of the strong field to the substance at low temperature often brought about a change of resistance of 30 per cent. or more. The presence of impurities always lessened the effect of the field on the resistance. "We find that, to insure that the impurities shall have only a small influence on our results the substance must in no case be less than 99.9 per cent. pure, and must be even purer in the case of lighter elements. If the substance is only 99 per cent. pure the influence of impurity is so large that the results are practically useless for our purpose." As some substances could not be obtained in the form of wire they were used as rods. Such were chromium and beryllium. Most, but not all, of the substances were tested at three temperatures, those of the room, of solid carbon dioxide and ether and of liquid nitrogen, respectively 290° K, 193° K and 88° K.

The results now to be presented are for the case when the magnetic field was at right angles to the current in the material

whose resistance was being measured. While the substance was maintained at a constant temperature the magnetic field was increased step by step and the ratio of the increase of resistance to the resistance at that temperature when no field was applied was calculated. The ratios of increase of resistances were plotted as ordinates against field strength in kilogauss as abscissæ. In most cases the curves starting from the origin had a concavity upward and finally changed into straight lines. Graphite and germanium in the fourth group of elements, tellurium in the sixth group and the magnetic elements iron and nickel in the eighth group depart from this standard form. In by far the greater number of instances the proportional effect on the resistance of applying the field of 300 k.g. is greater as the temperature of the experiment is lowered. For example in the case of a pure specimen of zinc at room temperature the action of the strong field caused the resistance to increase by .06; in $CO_2$ and ether the increase was .12 and in liquid nitrogen it was .915. For the elements of the fifth group the following are the increases for the three respective temperatures,—As, 1.1, 2.85 and 29; Sb, 3.5, 8 and 40 and for Bi, 37, 196 and 1360. This means that when the field of 300,000 gauss is applied to bismuth at liquid air temperature the resistance becomes 1361 times as great as it was without the field. Nickel alone was found to lose in resistance owing to the magnetic field.

The same experiments furnished an opportunity to examine the effect of reduction of temperature on resistance. Chromium immersed in liquid nitrogen, had only .083 of its resistance at room temperature. This was the smallest ratio noted. The following are corresponding ratios for other elements,—annealed copper, .141; Mg, .17; graphite, 1.6; Pb, .25; Bi, .346; W, .195 and Pt, .185.

The change of resistance with the magnetic field parallel to the conductor was likewise measured in a smaller number of cases. The proportionate increase of resistance when the field was applied was less than when the field and conductor were at right angles.

It might have been expected that the supra-conductors, mercury, thallium, tin, lead and indium would stand out in some way from the rest, but they showed no peculiar action. Their increases in resistance were, however, rather small. An alloy that is a solid solution, 75 per cent. gold and 25 per cent. silver, was tested. "No appreciable change of resistance was observed either at room temperature or at the temperature of liquid air. It is interesting to note that on cooling by liquid air the resistance of the wire diminished only to 0.87 of its value at room temperature." Another alloy, an artificially prepared mineral, $Cu_3As$, was studied. In

contrast to the other alloy its resistance grew greater upon application of the magnetic field.

G. F. S.

**The Ultra-violet Radiation of Bodies Acted on by Gamma Rays.** L. MALLET. (*Comptes Rendus*, Feb. 4, 1929.) The author has previously examined the ultra-violet spectrum emitted by pure water when gamma rays are falling upon it. It seemed that it had a limit set by the absorption of the glass of the prisms and lenses of the spectrograph used in the experiment. The present paper reports the advances made by the employment of quartz and rock salt to replace the glass of the instrument. In addition prisms with angles of 45° were used. These had quartz faces and were filled with water. The resulting spectra were very luminous but had little dispersion, a length of 22 mm. including wave-lengths from 4360 Å. to 2400 Å. The source of gamma rays was 250 mg. of RaE as sulphate contained in a glass tube which was placed in a sheath of lead 1 mm. thick. This disposition kept alpha and beta rays from escaping but permitted the exit of gamma rays. One side of the lead sheath was covered with sheet aluminium .5 mm. thick. This was put in contact with distilled water in a cell of black glass provided with a quartz window for the escape of the radiation developed in the liquid by the gamma rays coming from within the sheath. It was found that there was no noticeable result of the action of the rays on the material of the cell itself. The radiation from the water having emerged from the quartz window entered the spectroscope and after dispersion was recorded on the photographic plate, exposures ranging from 4 to 8 days being employed. Great precaution was taken to exclude parasitic radiation. Indeed a slab of lead 15 cm. thick was used for this purpose.

With water a continuous spectrum was obtained reaching from the visible wave-lengths to 2500 Å. For wave-lengths shorter than this the dispersion becomes greater and the sensitiveness of the plate smaller so that the photograph is not so easy to interpret. Carbon bisulphide under the action of the gamma rays also emits a continuous spectrum which, however, ceases abruptly at 3950 Å. where this liquid is strongly absorbing.

The author suggests that the penetrating gamma rays of the ground and of the atmosphere may produce feeble radiation, both visible and ultra-violet, in aqueous media especially in living organisms.

G. F. S.

**The Temperature of the Vapor Coming from a Boiling Solution.** K. SCHREBER. (*Zeit. f. Tech. Physik*, Vol. 9, No. 8.) Because the specific heat of water vapor is so small in comparison with the heat of vaporization it is very difficult to measure the temperature of the vapor arising from a solution in such a manner that no objection can be advanced against the method employed. There are two divergent views as to the relation of the temperature of the emergent vapor to that of the solution. Gay-Lussac held that vapor and solution have the same temperature while Faraday maintained that the temperature of the vapor is that of the pure liquid when boiling. Schreber has made a careful study of this question and decides in favor of Faraday's statement.

G. F. S.

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## JOHN PRICE WETHERILL SILVER MEDAL

to

**MR. CHARLES S. CHRISMAN**

for his

**Improvements in the Apparatus for and Methods of Gas Manufacture**

unless valid objection to the above proposed award, based on evidence of lack of merit, should be communicated, within one month of the date of this notice, to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia, Pa.

HOWARD McCLENAHAN,
Secretary.

Hall of the Institute,
July 1, 1929.